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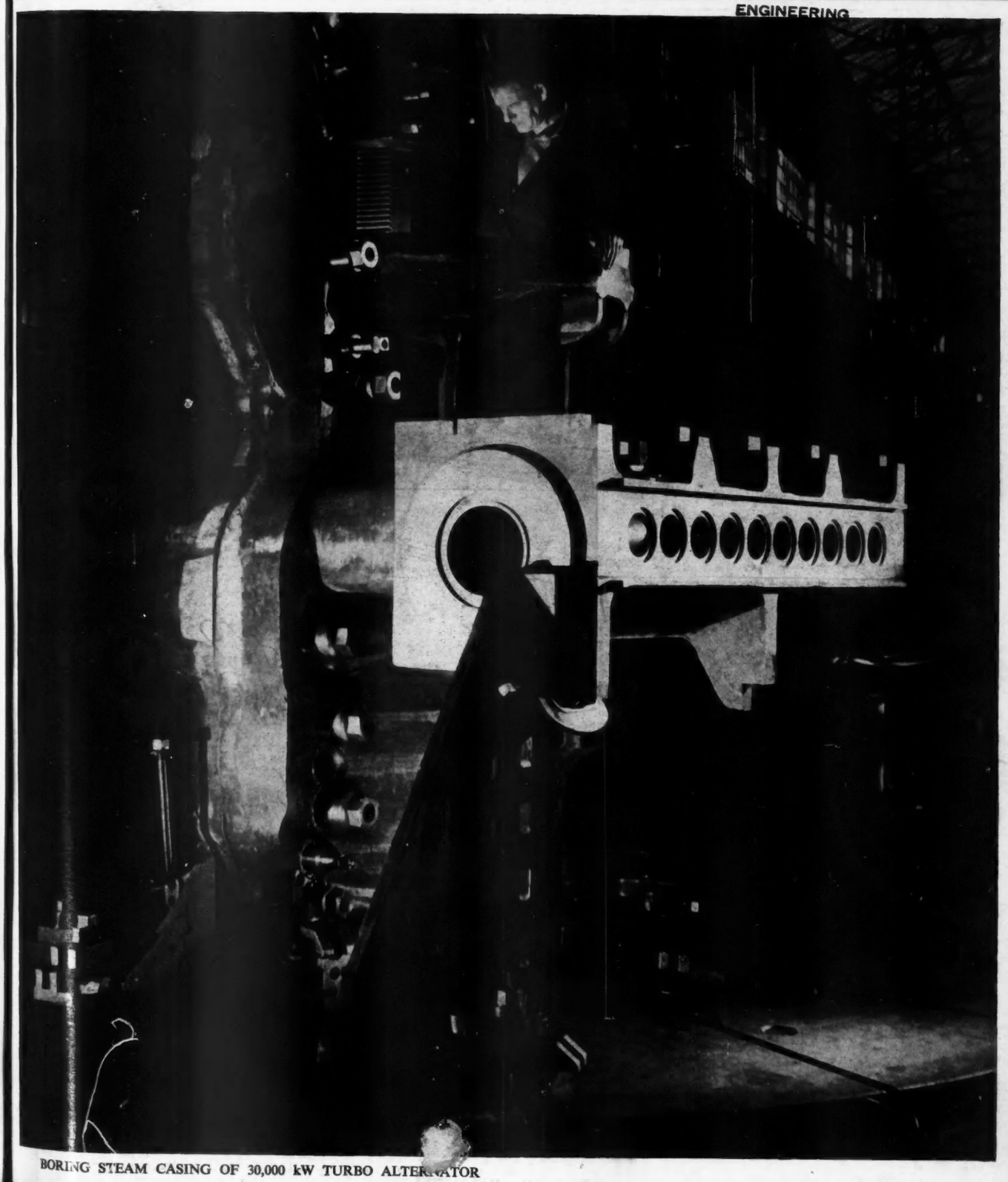
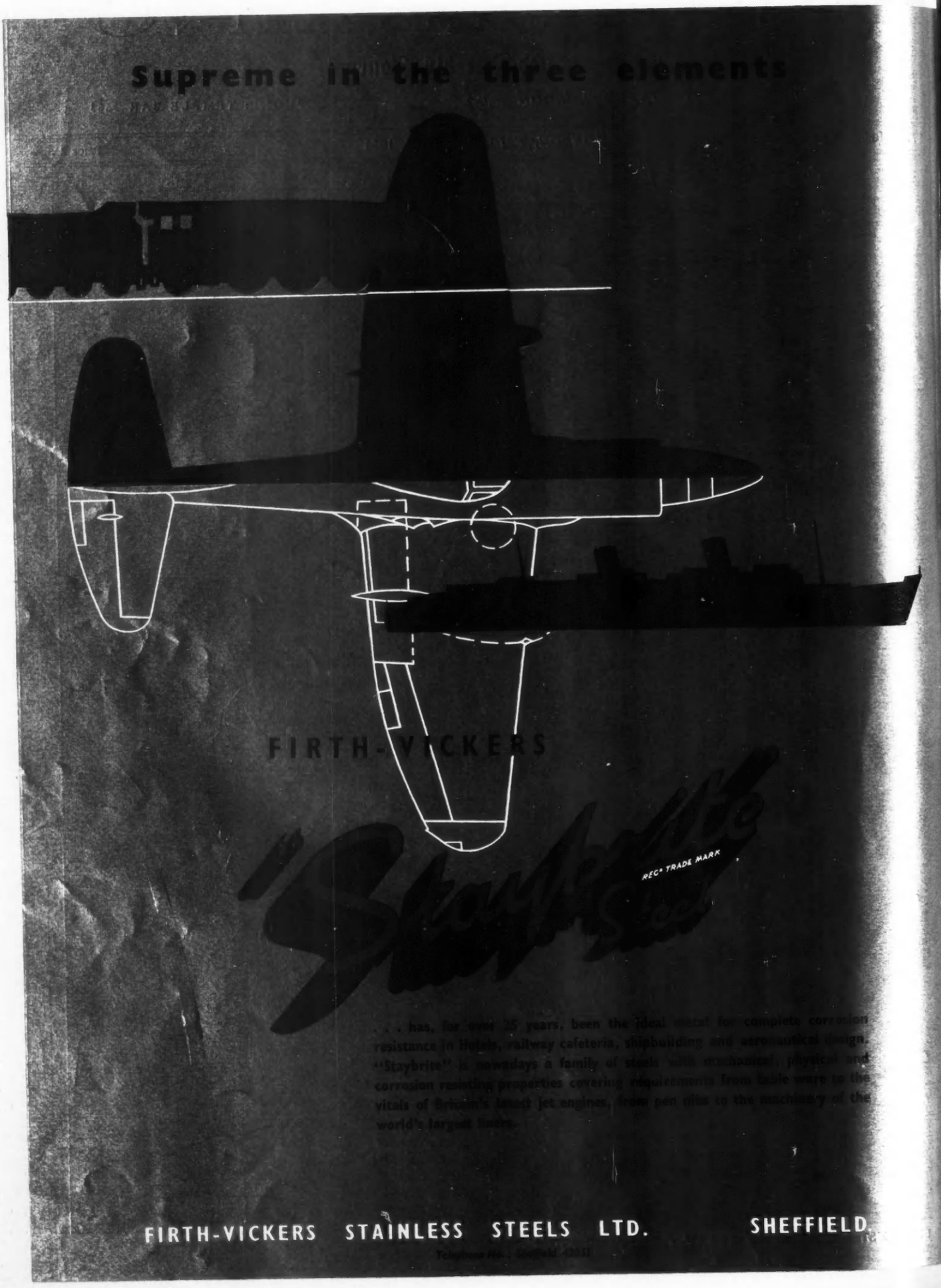


BORING STEAM CASING OF 30,000 kW TURBO ALTERNATOR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ENGINEERING

An Illustrated Weekly Journal

Vol. 177 No. 4610 JUNE 4, 1954

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ENGINES AND ENGINEMEN

THE unofficial strike on the Western Region of British Railways, by enginemen who object to working turns of duty which involve lodging away from home, was of more than trade-union significance. The attitude of mind which prompted it is in direct opposition to that striving for greater efficiency which has characterised the engineering and operating departments in recent years. British Railways are not likely to make unreasonable demands on the enginemen, but they have every right to expect the men to co-operate in the adoption of revised turns of duty which, it may be assumed, have been drafted in order to take full advantage of the latest improvements in steam locomotive design.

When it was decided, soon after the Railway Executive had been established by the Act of nationalisation, to build a series of steam locomotives which would be standard for all the Regions, one of the principal objectives was to provide the operating department with a series of engine classes so graded in power output as to meet, as closely as possible, the multifarious demands for engine power which the traffic makes. Twelve standard designs were therefore envisaged. The last of the twelve designs is described in this issue of ENGINEERING, though as only one engine has been built to this design it is not clear whether it is, in fact, to be regarded as the twelfth standard. Considerable importance has been attached to the ability of the engines to work over most of the railway routes and to be suitable for mixed traffic – passenger and freight. The British Transport Commission's executive officer (design), Mr. E. S. Cox, who was closely connected with the design of the locomotives under Mr. R. A. Riddles, remarked in a paper to the Institution of Locomotive Engineers earlier this year that it could no longer be argued that certain locomotives are more suitable than others for particular geographical areas of Great Britain. The construction of a single series of steam locomotives, he believed, could now be justified since "little is to be gained from mere diversity." The more responsible part of the controversy surrounding this question is concerned, as Mr. Cox recognised, lest in exchanging the four lines of development of the former railway companies for one, something valuable may be lost.

The evidence of Mr. Cox's paper should be sufficient to allay these fears. The overall efficiencies of several classes of locomotives running under "maximum sustained conditions" at 60 miles an hour vary only from 8·5 per cent. for a Western Region "Manor" class to 9·0 per cent. for a "Hall" class. In between are the British Railways' standard class 7 and standard class 4 4-6-0, the "King" class and the "V2" class (all at 8·9 per cent.), and the British Railways' standard class 5 (8·8 per cent.). The period of these designs covers more than two decades. Mr. Cox himself expresses the same idea in another way: "Whether twin or multi-cylinders, large or small wheels, wide or narrow grates, through considerable variations in back pressure, and either British, German or American design, a minimum steam consumption of 13 to 14 lb. per indicated horse-power-hour encompasses the lot, and boiler efficiencies at normal rates of working are closely alike."

There have, of course, been "teething" troubles with the standard designs; Mr. Cox referred to some of them. But they have been rectified and the locomotive engineers of British Railways are now striving after the further advances which appear to be open to steam traction. Apart from several basic modifications (higher superheat at low rates of working; abandoning the piston valve to solve lubrication and steam-leakage problems; utilisation of present sources of wasted heat in the boiler) Mr. Cox envisaged "a further onslaught on the unreliability of small details and continued attack on wearing parts for improved mileage between repairs."

Meanwhile the operating department are being provided with locomotives which match, more closely than ever before, their requirements for the optimum working of traffic. It has been found that if engines are rostered to work within steaming rates which are about 25 per cent. less than the maximum established by test, a satisfactory margin is left to absorb the effect of normal variations in coal and mechanical condition. The task of allocating the most suitable engines to the trains to be worked – "diagramming" as it is called – is extremely complex. Mr. L. C. Welborn has said, in another recent paper to the Institution of Locomotive Engineers, that if it can be done efficiently the fullest advantage can be taken of all those features of design which have improved locomotive availability. There are no glittering prizes to be won by pursuing this policy, but at present it is the only practicable policy open to British Railways. Even if the enginemen choose to forget their customers and think only of themselves – which is clearly what they have done – it would pay them, in the long run, to respond wholeheartedly to the lead given by their locomotive engineers.

Weekly Survey

LOCOMOTIVE EXPORT DELIVERIES IMPROVED

A marked improvement in the supplies of steel plate during the past few months is enabling British builders of locomotives to quote quicker deliveries. This is specially welcome since much ground has been lost in the past two years to foreign competitors, particularly to those from Germany and North America, through long delivery delays. Some goodwill was also lost, particularly in the Union of South Africa where earlier this year the Minister of Transport complained that only 23 of 40 electric locomotives promised by the end of 1952 had been received, and that the delivery of 50 steam locomotives had been delayed nine months.

An improvement is urgently needed: orders for steam locomotives have been very disappointing for over a year and there is a threat of serious unemployment in several works of the steam locomotive builders. The latter also make the mechanical parts of Diesel, Diesel-electric and electric locomotives, but despite the better level of orders for this type of motive power they cannot hope to maintain a balanced load on their workshops unless more orders are obtained for steam locomotives. The change in demand since the war, however, in favour of Diesel-electric traction, has been more radical and quicker than was anticipated. British Railways are now the largest users of steam traction in the world, and show no signs of a general change-over to Diesel, but they cater for over 95 per cent. of their needs in their own workshops and it is most unlikely that they will give private builders the orders they need to offset losses in export markets.

The ability of the British locomotive industry to compete with American and continental builders was demonstrated most convincingly last month when the Irish State Transport awarded to the Metropolitan-Vickers Electrical Company, Limited, a contract for 94 Diesel-electric locomotives worth £4¾ millions. There is no doubt, however, that the greater proportion of overseas development which is being financed by foreign capital has influenced the placing of orders in other countries. Other adverse factors have been the reluctance of the Treasury to sanction and of British builders to offer long-term credit, or to send out engineers and technical advisers in sufficient numbers to match the assistance given by the United States, Germany and other countries. Unfair competition, particularly from Germany, has been alleged repeatedly during the past few months. Last December Mr. Heathcote Amery, Parliamentary Secretary to the Board of Trade, said that there was no evidence of any direct subsidy by the German government, but British builders feel that the tax remissions granted to exporters have been the principal factor in lower German prices during 1953, when they were on an average about 10 per cent. below the British. Canada's gift to India of 120 locomotives under the Colombo Plan shows how much easier it is for an industry enjoying the advantages of an assured home market to bear what may have meant a substantial loss on a large export order to keep output at a high level.

British builders are also being handicapped by their inability to quote firm prices, owing to the uncertainty of engineering wage awards. There is a growing reluctance on the part of importing countries to place orders unless firm prices are quoted, and since this is being done by most of their foreign competitors, there is little doubt that British builders will be forced to follow suit and take the risk. The improvement in the delivery position should assist them to do this, and there is every hope that they will increase their share of world demand.

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BURMA'S DEVELOPMENT PROGRAMME

A programme of development planned by the Government of the Union of Burma which involves expenditure amounting to 7,500 million Kyats – approximately £560 millions – during the next seven years was described as " vast and courageous " by the President of the Board of Trade, Mr. Peter Thorneycroft, in a foreword to the report of a United Kingdom delegation, headed by Lord Burghley, which went to Burma in March to obtain first-hand information about the programme. This report, published last week (H.M. Stationery Office, price 2*s.* 6*d.*), gives details of the various schemes that have been approved and points out " those spheres in which United Kingdom consultants and industrialists can participate to the mutual benefit of both countries." The plans, approved by the Burmese Government last February, were prepared by a group of United States consultants, known as Knappen-Tippetts-Abbett-McCarthy Engineers (K.T.A.M.), who were engaged to undertake an economic and technical survey of the country, as part of the American Aid programme for Burma.

The domestic policy of the Burmese Government is devoted to the creation of " Pyidawtha," or the Welfare State. Rapid progress in raising living standards is considered an effective way of reducing Communist influence on the Burmese people, without whose support the insurgency could not go on. The K.T.A.M. plans are for an intensive development of the country's natural resources and for the establishment of manufacturing units to process Burmese raw materials and primary products, and to make relatively simple constructional, agricultural and packaging products to service the primary industries. To make this possible there are plans for a large expansion and modernisation of the rail, air and telecommunication services, inland waterways, roads and port facilities and for the provision of new generating capacity.

Much damage has been caused by the war and the subsequent insurgency and will have to be made good before output of primary products and raw materials can be increased, even to the pre-war level. Rice exports are little more than one-third of the pre-war average, exports of teak and other hard woods have almost ceased, oil production is about one-seventh of pre-war, and ore extraction from the Baudwin and other mines is only about one-fifth. K.T.A.M. recommend mechanisation to increase output of primary products, particularly hardwoods. Rice yield per acre is being increased, and other main crops – pulses, sesamum, groundnuts, cotton, wheat and tobacco – are to be developed.

Industrial projects comprise the building of 70 factories, of which 18 are already in hand or will shortly be implemented. They include a steel rolling mill, to be built by a German firm, which will operate on local scrap. The main factories for which tenders have been received or requested include a jute bag and twine mill with an estimated output of 24 million bags a year; two sugar factories; a bamboo pulp and paper mill; two textile mills, one of which will spin local cotton to supply coarse yarn to the Burmese cottage weaving industry and the other will spin and weave fine counts from imported cotton; a tin refinery; a shipyard where it is proposed to build 5,000-ton to 10,000-ton ships; and factories to produce rubber manufactures, sulphuric acid and fertilisers, rice bran oil, agricultural implements, glass, ceramics, metal containers, cement and copper wire. The industrial plans appear to be soundly based on the resources and basic needs of the country.

Electric power projects include an addition to the Rangoon thermal power station, to be supplied with coal from a newly-discovered seam on the Chindwin river (to take the place of expensive Bengal coal), and three hydro-electric power stations with a total capacity of about 50 MW, rising to 80 MW. The port of Rangoon is to be re-built and extended, inland waterways will be supplied with ten new paddle steamers, and the railways rehabilitated and provided with 31 locomotives and railcars, including six main-line Diesel-electric locomotives. In addition, improvements and extensions costing over £60 millions are to be made to the road network (involving extensive mechanisation of road building), to air transport (£6·5 millions) and to telecommunications (£2·2 millions). Of the total expenditure envisaged (£560 millions), the development of electric power will take about 13 per cent., roads about 11 per cent., ports and waterways 7½ per cent., resources (canals, dams and irrigation schemes) 6 per cent., railways 3½ per cent., water and industrial plants 3 per cent.

This is a bold programme, dependent for its realisation on foreign capital to the extent of £190 millions – one-third of the total - and to a much greater extent on foreign technologists and managerial skills. The Burmese Government have made it plain that they want to use, not serve, foreign investors. At the same time the latter are to have a share in the control and execution of the various schemes, to the limit possible without giving extreme nationalists and communists a dangerous weapon against the Government.

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TRAINING ENGINEERS FROM OVERSEAS

The delegation to Burma emphasised in their report that the training of Burmese engineers and technologists in Britain was a most important step in securing the goodwill of the Burmese Government and in cementing the friendship between the two countries. They pointed out that this was a measure of self-interest: " there is a very serious shortage of technicians and tradesmen of all types and, unless something can be done to improve this position, there is a great danger of the mechanical equipment, which the Government will be buying for their very bold programme, being out of action for long periods due to lack of proper maintenance." The Federation of British Industries have published a booklet this week – *F.B.I. Overseas Scholarships: Training Overseas Engineers as an aid to Future Exports* – which deals with this very subject.

The F.B.I. booklet points out that most countries where there is a market for British plant and equipment insist on controlling the operation and maintenance of new capital projects, and frequently their construction, through engineers of their own nationality. They must continue to import, however, as in the case of Burma, technical advice, plant and machinery for new installations, and the equipment required for their construction. This has created a vast demand for training facilities for foreign and Commonwealth nationals, greatly in excess of what is available. But unless such facilities are provided in this country, Burmese, Indians, Latin Americans and others will look

for them in other countries, particularly in the United States, Germany, Japan and the Soviet Union, to the eventual detriment of British exports and British political influence. One of the greatest needs of our engineering companies is to know in good time – long before tenders are requested – the development plans and capital projects in overseas countries, and to have in each some friends among the engineers responsible for placing contracts for industrial equipment. As the F.B.I. point out, one of the best ways of ensuring this is to train them in Britain: "We help them and their countries by giving them the best training in the world; we help ourselves because they return home with first-hand knowledge of the range and quality of our engineering products and the personal contacts made contribute materially to international goodwill."

The booklet lists the names of 53 engineering firms who had accepted F.B.I. scholars by the end of March, 1954, and states that a further 97 firms have agreed to accept scholars for training. Many more are needed, however, to cater for the specialist requirements of the large number who will arrive annually when the scheme is in full operation. There are obvious difficulties to be overcome if the number of graduate apprentices receiving training in the United Kingdom is to bear some relation to the demand from overseas. The lack of training facilities is probably the main obstacle, but there is also in some cases the need to keep secret certain processes or products, and the natural reluctance to spend money educating future competitors. The shortage of facilities will be hard to overcome, as relatively few firms run graduate apprentice schemes, and those who do cannot increase the number of students beyond that which can be accommodated in their works without disrupting production. All firms will obviously continue to give priority to their own apprentices and to those nominated by their associated companies or agents overseas. The success of the F.B.I. scheme will depend mainly on the breadth of industrial support it is likely to get. The export performance of the Metropolitan-Vickers Electrical Company, Limited, who have trained 3,000 graduates – one-third of them from overseas – since they started their scheme in 1902, shows that such a policy pays dividends.

The booklet gives details of the scheme, and shows how its cost is shared by the F.B.I., the Government and the participating companies. The excellent arrangements the F.B.I. have made for the selection of candidates, starting in the countries of origin and ending in London, should go far to encourage companies who may have wished to take overseas students but have been deterred by the difficulties of selection.

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REVISED SMOKE NUISANCE LAW

The National Smoke Abatement Society have put forward a memorandum of proposals for action to the Government Committee on Air Pollution (the Beaver Committee), in which they contend that the smoke-nuisances section of the Public Health Act is in need of revision.

The present law, it is stated, has scarcely changed at all during the past 75 years and needs so much amendment that it should be repealed in its entirety and replaced by new law. Provisions that the Society would like to see in the new law include: more stringent control methods for checking any smoke that may be emitted; prior approval of all new fuel-burning installations (except domestic, for which only approved appliances should be sold); ability of local authorities to set up smokeless zones without having to promote private Bills. To ensure that the law is complied with, it should be obligatory for all local authorities to employ qualified smoke inspectors, or alternatively to join together as Joint Air Pollution Control Committees to do so. If neither course is taken then the county council should take over. The law should require all boiler and furnace firemen to possess a certificate of proficiency.

The Society recommend that the Government should make smoke prevention one of the primary factors in all fuel policy questions; that the proposals that the Ridley Committee and the fuel conservation team of the British Productivity Council have already made should be implemented; that smokeless-fuels production should be developed, and more of these fuels should be switched to domestic use, especially in the "black spots"; that more research should be undertaken on outstanding problems; that local authorities should be encouraged; and that a standing Government organisation or committee should be set up to keep the problem under continuous review.

Local authorities are urged to make full use of their existing powers to abate smoke and should employ fully qualified inspectors. They should directly encourage the use of smokeless methods and should include smoke prevention as part of their statutory health education propaganda. Pollution from industrial sources could be largely prevented by the greater co-operation and pooling of knowledge by industry itself. Trade associations and chambers of commerce should assist individual firms and they should also start or extend research and the field study of particular problems. Trade unions should co-operate in and foster schemes for the training and qualification of stokers.

The memorandum reminds the committee that the previous Government committee (in 1920) concluded that "no Government has, for many years, taken any action with the exception of appointing committees, whose labours have had little or no result." The first step in creating the public opinion necessary to prevent this happening again, it is suggested, can be the Beaver Committee's own report, which "should make a sharp and compelling impact in responsible quarters."

Copies of the memorandum may be obtained from the National Smoke Abatement Society, 30, Grosvenor-place, London, S.W.1, price 1*s*.

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MARKETS IN THE MIDDLE EAST

The trade mission to the Middle East, which visited Iraq, Kuwait, the Lebanon, Syria and Saudi Arabia last November under the chairmanship of Sir Edward Benthall, issued its report last week. The opportunities which now exist in this market for British exports can be summed up in the fact that British exports to these five countries increased from £3 millions in 1938 to a rate of about £71 millions in 1953. This striking growth of trade has been achieved in the face of severe competition from the United States and Germany. The mission has been impressed with the still greater amount of trade which could be obtained if this competition were more aggressively and successfully challenged by British companies. Iraq, Kuwait and Saudi Arabia each have a revenue from oil alone amounting to between £50 and £60 millions a year which provides a very adequate financial basis for capital development programmes.

The mission calls special attention to such sales factors as goodwill, prices, firm quotations, deliveries, service, quality and design, courtesy and publicity. They have also noticed the difficulty which British companies have in appointing local agents with sufficient experience to handle their products. This is at least one point from the report which British companies will endorse. An intensive drive will be necessary, according to the report, if progress is to be maintained, because over-stocking on the spot, coupled with prices and deliveries which do not compare favourably with competitors, have lost ground for this country in Syria, the Lebanon and Saudi Arabia, though ground has been gained in the Persian Gulf area. Repeated complaints were encountered by British representatives that business was being lost because of the extended credit facilities offered by competitors on both capital, semi-capital and consumer goods. They therefore recommend that a further examination should be made of the credit facilities available to British exporters, particularly of consumer capital goods, and that wider publicity should be given to the facilities offered by the Export Credits Guarantee Department. On export incentives, the mission support the policy of restricting export incentives by international action and they point out strongly that the whole structure of taxation in this country provides a strong deterrent to the taking of risks in these markets by exporters of all kinds.

There are indications that British industry is fully aware of the opportunities which are developing in the Middle East for their exports. The British Trade Fair which is being organised by the Federation of British Industries in Baghdad in October is reported to be already fully booked so far as space is concerned, and it is known that a number of engineering companies are going to use the Fair as the starting point for an export drive in the Middle East. For such companies, and for many others whose products might profitably be offered more systematically and aggressively to this market, the mission's report on the trading conditions in each of the five countries will be a valuable guide.

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Letters to the Editor

DRAWINGS IN "ENGINEERING"

Legibility of Back-Lining

SIR, I was very interested in the comments by Mr. Welbourn (page 611, May 14) on the back-lining of drawings. It seems to me, however, that he is missing one simple but important point in assessing values.

When a draughtsman prepares a drawing he should obviously employ a technique which will best suit the occasion on which the drawing will be used. Drawings for use in the workshop should be fully dimensioned, with clear-cut projectional views and lettering. The machine and bench worker has little time for solving puzzles. Drawings for publication are generally not fully dimensioned and are intended to give thousands of engineers and associates a clear picture of the functioning of mechanisms, with as few projectional views as possible. Therefore back-lining can usefully be employed in this type of drawing, giving, to a certain degree, a three-dimensional effect. If anyone cares to examine the files of specifications at H.M. Patent Office some good examples of back-lining technique may be found; bearing in mind, of course, that Patent Office rules require no dimensions. Your comments on his letter are, of course, very true and I agree with them wholeheartedly.

Your faithfully,

A. TOMLINSON.

10 Greenwood Way,
Sevenoaks, Kent.
May 31, 1954.

A TRACTOR WITH HYDRAULIC TRANSMISSION

PROTOTYPE DESIGN OF THE N.I.A.E.

In continuation of the policy of holding "open days," the National Institute of Agricultural Engineering, at Silsoe, Bedfordshire, was opened for inspection on Wednesday and Thursday last week so that interested parties could view the work and discuss with members of the staff the many projects in hand. Wisely, the Institute hold these open days every other year, it being their view that, as much of the work in hand is of a long-term nature, there is little to be gained by holding them every year. Despite the long-term nature of several of the projects, however, there was much that was new on show this year. Undoubtedly the most interesting item of equipment coming under this heading was the hydraulically-propelled tractor illustrated on this page. This machine embodies, in a slightly modified form, the hydraulic motors described by Mr. H. J. Hamblin, B.A., head of the Mechanical Engineering Department of the Institute, in his article entitled "Hydraulics in Agricultural Engineering."*

As Mr. Hamblin pointed out in his article, the possibility of using a hydrostatic transmission for propulsion is not a new idea; indeed, its use in connection with automobiles was considered very early in their development. Briefly, the advantages claimed for this form of propulsion are: replacement of the conventional clutch control and gear lever by a single lever; provision of more space for mounting implements; and reduction of the risk of user damage. So far as the replacement of the clutch pedal and gear lever is concerned, this not only leads to more simple control of the tractor, but the very nature of the hydraulic transmission gives stepless speed control from full speed forward to full speed in reverse. Furthermore, the operator can obtain exactly the speed he wants and can change speed while the tractor is moving.

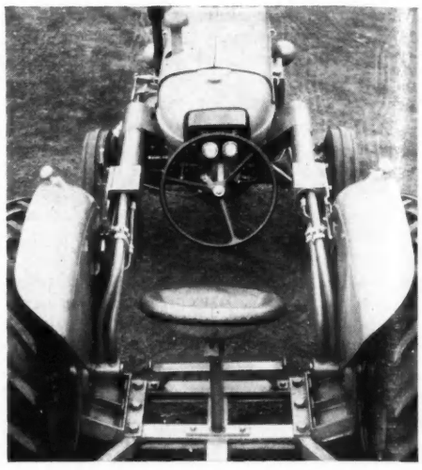
OIL CIRCUIT

In general, the design of the hydraulic-transmission gear fitted to the tractor on view at Silsol follows very closely that described by Mr. Hamblin in his article. There are two hydraulic motors, each of which is enclosed in one of the rear wheels. Each unit has five cylinders disposed radially which are arranged to rotate round a stationary shaft with a fixed eccentric carrying a roller race, on the outside of which bear thrust pads from each of the five pistons. The oil is distributed to the cylinders by means of a pipe through the fixed shaft which feeds a rotary face valve, loaded automatically by oil bled from the pressure line. Exhaust oil is returned through the same valve and fixed shaft, and it will readily be appreciated that reverse motion can be obtained by reversing the flow of the oil. To enable the tractor to be operated at speeds varying from a slow crawl to approximately 12 miles an hour without using an excessively large pump, the motors are designed so that they have two capacities. This is achieved by making each piston from two parts, namely, a central ram surrounded by a sleeve, the design being such that the sleeve can be secured at top dead centre by a hydraulically-operated catch, thus reducing the effective area of the piston from that of the cylinder to that of the central ram, the cylinder capacity thereby being reduced.

The pump unit consists of a standard Fordson tractor engine arranged to drive the output section, a pump of a Vickers V.S.G. unit. The pump is disposed at one side of the engine and is driven from the engine crankshaft through a chain. It has a maximum output of 60 gallons per minute and a maximum operating pressure of 2,000 lb. per square inch. The position of the pump swashplate, and hence the output of the pump, is controlled by a small lever conveniently disposed to one side of the driving position. This lever is used, of course, not only to determine the output of the pump but also to reverse the flow of oil. The only other control is an engine speed control which, in accordance with standard tractor practice, operates through a variable-speed governor. It will be appreciated that control of the tractor is exceptionally simple as all speeds both for forward and reverse directions of travel are obtained by altering the position of the lever. Furthermore, to reverse the tractor merely entails moving the lever from the forward to the rear position.

There is an auxiliary hydraulic circuit for making up slip losses, etc., in the main circuit. It consists of a vane-type pump driven by the engine which draws oil from the reservoir and delivers it through a filter and relief valve to a directional control valve; this automatically directs the replenishment oil into the low-pressure side of the circuit. Surplus oil collecting in the hydraulic motors is returned to the reservoir automatically by the resultant build-up of pressure.

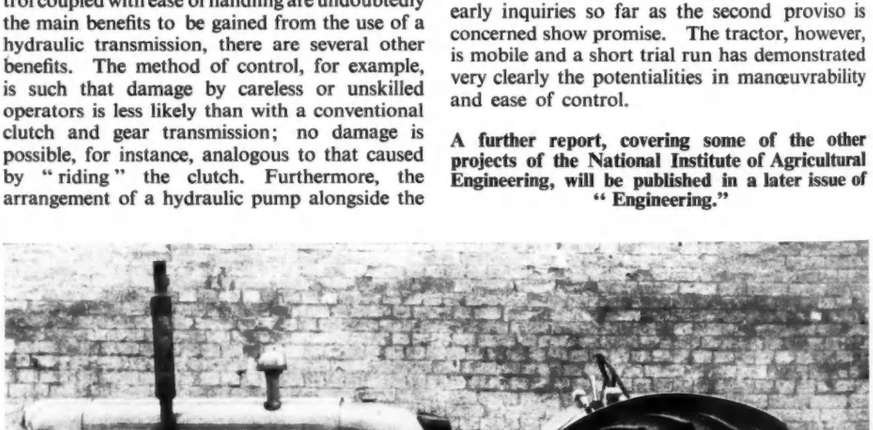
Although the provision of stepless speed control coupled with ease of handling are undoubtedly the main benefits to be gained from the use of a hydraulic transmission, there are several other benefits. The method of control, for example, is such that damage by careless or unskilled operators is less likely than with a conventional clutch and gear transmission; no damage is possible, for instance, analogous to that caused by "riding" the clutch. Furthermore, the arrangement of a hydraulic pump alongside the power unit, with hydraulic motors built into the driving wheels, provides considerably more space for mounting implements. This applies particularly to those implements mounted beneath the tractor, such as cutter bars, hoes, etc., as it will be seen from the illustrations that the space available for these is quite exceptional.



A great advantage of the N.I.A.E. hydraulic tractor is the large amount of space made available for mounting agricultural implements.

It should, perhaps, be emphasised that the tractor is quite new and was only completed some two weeks before the open days. It has, therefore, not been tested or, in fact, put under load at all, and it is envisaged that a considerable amount of experimental and development work will have to be carried out. Furthermore, it remains to be seen whether the system is satisfactory technically and commercially feasible, but early inquiries so far as the second proviso is concerned show promise. The tractor, however, is mobile and a short trial run has demonstrated very clearly the potentialities in manœuvrability and ease of control.

A further report, covering some of the other projects of the National Institute of Agricultural Engineering, will be published in a later issue of "Engineering."



The prototype tractor with hydraulic transmission, developed at the N.I.A.E., ran for the first time recently. The pump unit, mounted on the left of the engine, delivers oil to a five-cylinder motor in each wheel. Speed control is infinitely variable.

* See ENGINEERING, vol. 173, page 637 (1952).

THE IRON AND STEEL INSTITUTE

ANNUAL GENERAL MEETING

The 85th annual general meeting of the Iron and Steel Institute was held in London on the mornings and afternoons of Wednesday and Thursday, May 26 and 27. The first session of the meeting, on the morning of May 26, was held at the Royal Institution, Albemarle-street, W.1; the remaining three sessions were held at the offices of the Institute, 4, Grosvenor-gardens, S.W.1. At the outset of the proceedings, the retiring President, Mr. James Mitchell, C.B.E., occupied the chair.

REPORT OF COUNCIL

The President then presented the report of the Council for 1953. The report showed that the total membership of the Institute on December 31, 1953, was 4,925, compared with 4,801 on December 31, 1952. A lease had been signed for a 60 years' tenure of the offices at 4 Grosvenor-gardens, as from September 25, 1955, when the present lease expired. The terms included the payment of the sum of £41,620 and a rent of £400 per annum. Forty-five companies connected with the steel industry had generously contributed a total of £53,700. The Council had decided that the balance, after the payment of the capital outlay and connected expenses—a sum exceeding £10,000—should be earmarked for a house fund and suitably invested. The Council had decided that, as from 1954, the pre-war practice of striking the Bessemer Medal in gold should be resumed.

PRESENTATION OF MEDALS AND PRIZES

Mr. Mitchell then presented the medals and awards made during the year. The first, the Bessemer Gold Medal for 1954, was handed to Dr. T. P. Colclough, C.B.E., M.Met., F.R.I.C., technical adviser to the British Iron and Steel Federation, in recognition of his distinguished contribution to the development, in theory and practice, of the manufacture of iron and steel. In returning thanks for the honour conferred upon him, Dr. Colclough paid tribute to the influence of Professor F. C. Thompson and the late Dr. W. H. Hatfield, F.R.S., during the early days of his career in the steel industry.

The Sir Robert Hadfield Medal for 1954 was presented to Dr. A. H. Leckie, B.Sc., F.R.I.C., technical officer to the Iron and Steel Board and, until recently, with the British Iron and Steel Research Association, in recognition of his valuable contributions to research in steelmaking.

An Andrew Carnegie Silver Medal for 1953 was handed to Mr. G. R. Bish, M.Sc., of Enfield Cables, Limited, and formerly of University College, Swansea, for his report (written in conjunction with Professor H. O'Neill, who was not eligible) on "The Deformation of Austenite in Relation to the Hardness Characteristics of Steel."

Two Williams Prizes were awarded for 1953, each being of £100. One was handed to Mr. A. H. Norris, of John Lysaght, Limited, Scunthorpe, for his paper, "Soaking-Pit Practice at the Normanby Park Steelworks," and the other to Mr. E. R. S. Watkin, of the Appleby-Frodingham Steel Company, for his paper, "Railway Traffic of the Appleby-Frodingham Steelworks."

Finally, the Ablett Prize for 1953 was presented to Mr. F. Starkey, of Buckley and Taylor, Limited, Oldham, for his paper, "Guides and Strippers for Modern Rod and Bar Mills," to be published later in the *Journal* of the Institute.

FUTURE MEETINGS

The secretary announced that the special meeting in Sweden would be held from June 7 to 18, 1954, and that the autumn general meeting would be held in London on November 24 and 25, 1954, to be followed on December 1 and 2 by a "Symposium on Powder Metallurgy."

In June, 1955, a joint metallurgical societies meeting would be held in Europe. The American Institute of Mining and Metallurgical Engineers and the American Society for Metals had accepted invitations from the Iron and Steel Institute, the Institute of Metals and the appropriate societies in France, Germany and Sweden to send representatives to a meeting in Europe. This would open in London on Wednesday, June 1, 1955, and would continue in this country until June 8. The second section would be in Düsseldorf from Thursday, June 9, until Sunday, June 12. A visit would be paid to Liége on June 13 and the third section of the meeting would be held in France from June 14 to 19.

INDUCTION OF NEW PRESIDENT

At this stage of the proceedings, Mr. Mitchell inducted the President-elect, the Hon. R. G. Lyttelton, into the chair and, in doing so, recalled Mr. Lyttelton's services to the Institute as honorary treasurer. After a vote of thanks to the retiring President had been passed with acclamation, Mr. Lyttelton delivered his presidential address which was entitled "Social Consequences of Iron and Steel." An abridgement of it is on page 713 of this issue of ENGINEERING.

After a brief interval, Dr. T. P. Colclough delivered the seventh Hatfield Memorial Lecture on "Developments in the Iron and Steel Industry in Great Britain during the Last Twenty-Five Years." In his lecture, Dr. Colclough stated that the period 1929 to 1939 had been one of experimenting; the war years 1939 to 1945 had been largely static as regards the building of plant, but during this period the emphasis had been on the production of increasing supplies of alloy and other high-grade steels. The period 1945 to 1954 had seen the consummation of the forward policy initiated prior to the war, involving the building and setting to work of large completely-integrated plants turning out wire, tubes and other finished products from the two raw materials, coal and iron ore.

The afternoon of Wednesday, May 26, and the whole of Thursday, May 27, were devoted to the presentation and discussion of papers.

ANNUAL DINNER

In proposing the toast of the "Iron and Steel Institute and Industry," at the annual dinner of the Institute held at Grosvenor House, Park-lane, on the evening of May 26, Mr. Harold Macmillan, P.C., M.P., Minister of Housing and Local Government, said that the iron and steel industry had been made great and maintained great by research. It was due to this spirit that high-quality steels were made from low-grade ores, often containing less than 30 per cent. of iron. Important increases had also been made in outputs; in the first quarter of the present year the annual production rate for pig iron had been nearly 12 million tons and that of steel nearly 19 million tons.

In the course of his reply, the President, the Hon. R. G. Lyttelton, referred to the co-operation between producers of iron and steel which had received great encouragement by the foundation, in 1918, of the National Federation of Iron and Steel Manufacturers, and had proceeded to an increasing extent during the subsequent years. Co-operative research, begun by the industry, had received the whole-hearted support of the Government and the British Iron and Steel Research Association was now the largest research association in this country.

The toast of the guests was proposed by Sir Charles Bruce-Gardner, Bt., and the response was by the Very Reverend A. C. Don, K.C.V.O., Dean of Westminster.

Reports of the technical papers and discussions, and of the Hatfield Memorial Lecture, will be given in subsequent issues of "Engineering."

THE INTERNATIONAL RAILWAY CONGRESS

The 16th session of the International Railway Congress Association, held in London from May 19 to 26, brought together more than 500 delegates, with their ladies, from numerous Continental and overseas railways. The last London session was held no less than 29 years ago, when the centenary of the Stockton and Darlington Railway was being celebrated.

At the formal opening ceremony at Church House, Westminster, on Wednesday, May 19, H.R.H. The Duke of Gloucester welcomed the delegates on behalf of H.M. The Queen. The Duke said that the Association, since its foundation in 1885, had proved a valuable forum for the interchange of railway information. As the pioneer of railway development, the United Kingdom had always taken a great interest in developments in other countries.

Mr. De Vos, President of the Association, thanked His Royal Highness for having graciously accepted the office of Honorary President of the present session. A welcome on behalf of Her Majesty's Government was extended to the delegates by the Minister of Transport and Civil Aviation, the Rt. Hon. Alan Lennox-Boyd, and on behalf of British Railways and London Transport by Sir Brian Robertson, chairman of the British Transport Commission. The opening ceremony was held in the Hoare Memorial Hall of Church House—the meeting place of the House of Commons on many occasions during the war and the scene of some of Sir Winston Churchill's most famous speeches.

On the subsequent days of the Congress, the delegates divided into sections to discuss various subjects, including maintenance of the permanent way, modernisation of station buildings, methods of financing modernisation, the relative advantages of various electric traction systems, improving the efficiency of steam locomotives, radio-phonic communications in railway working, staff recruitment, railway participation in road transport, and the protection of electric equipment. The detailed reports on these subjects had already been published (some of them have been summarised in recent issues of ENGINEERING) and the delegates were, therefore, confined to discussing the form that the agreed conclusions should take.

The Locomotive Manufacturers' Association of Great Britain were the hosts at a banquet held at the Savoy Hotel on Friday, May 21. In proposing the toast of the Congress, the president of the Manufacturers' Association, Mr. John Alcock, said that in this country we were proud of the fact that a large proportion of the world's locomotives were British. "You who come from abroad," he said, "may not know that British Railways build most of their own locomotives. Over 95 per cent. of the locomotives we build are sent abroad." The reply to the toast was made by Sir Gilmour Jenkins, Permanent Secretary of the Ministry of Transport.

The British Transport Commission gave a dinner to the delegates at Grosvenor House on Tuesday, May 25. Mr. Lennox-Boyd, proposing the toast of the Congress Association, recalled some of the early history of railways and remarked that Lord Hurcomb, who was present at the Congress, had been a delegate at the time of the previous London session in 1925. Mr. De Vos responded to the toast. Sir Brian Robertson, proposing the toast of the guests, welcomed them and went on to say that the railways must be kept up to date. If there was to be a bright future for the railways the attitude of those who worked for them was important. That should be remembered by everyone from the chairman down to the cleaner, porter, stoker, or lengthman. Service must come before self.

During the course of the Congress the delegates enjoyed the hospitality of a large number of engineering firms up and down the country. They also took part in numerous excursions and attended a performance of *The Sleeping Beauty* given by the Sadler's Wells Ballet at the Royal Opera House, Covent Garden, on May 26.

INDUSTRIAL USES OF ELECTRONICS

Meeting at Oxford University

Arrangements have been made by the British Institution of Radio Engineers to hold their third post-war convention at the University of Oxford from Thursday, July 8, to Monday, July 12, 1954. The main object of the convention will be to show how the use of electronics can increase production in quality and quantity.

During the first four days of the convention, some 30 papers will be presented, dealing with computors for industrial and commercial use, industrial X-ray equipment and the use of ultrasonics, nucleonic instrumentation, transducers in industrial production, and the various applications of electronics to process control. At the final technical session, on July 11, there will be a discussion on "Industrial Aids to Production," at which the chair will be taken by Sir Walter Puckey, President of the Institution of Production Engineers.

Sir John Cockcroft, K.C.B., F.R.S., Director of Research, Atomic Energy Research Establishment, Harwell, will deliver the Clerk Maxwell Memorial Lecture of the British Institution of Radio Engineers at the Clarendon Laboratory, Oxford, on July 8, commencing at 8 p.m.

A banquet has been arranged to take place on July 9, and the last day of the convention, July 12, will be devoted to various visits and demonstrations. Advance proofs of papers will be available. Applications to attend the convention should be sent to the British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1.

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OPEN-HEARTH FURNACE FLAMES AND OUTPUT

Glasgow Conference

An all-day conference on "Open-Hearth Flames and Output" has been organised by the West of Scotland Iron and Steel Institute and will be held at the Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2, on Friday, September 10, 1954.

Subjects discussed in the morning will include the combustion and radiation characteristics of oil and coke-oven gas jet flames, melting rates in open-hearth furnaces, improvements in firing oil and coke-oven gas in open-hearth furnaces, producer gas as a competitive fuel, and the use of various fuels in open-hearth furnaces.

The afternoon will be devoted to a discussion, opened by Mr. R. W. Evans, chairman of the steel practice committee of the British Iron and Steel Research Association.

Applications to attend the conference, should be addressed to the secretary of the West of Scotland Institute at the above address. The registration fee is 7*s*. 6*d*, and preprints of the papers may be obtained at 15*s*. a set.

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SAFETY IN CHEMICAL WORKS

Harrogate Conference

Arrangements are being made by the Association of British Chemical Manufacturers to hold their fifth Chemical Works Safety Conference from Friday afternoon, November 5, to Sunday morning, November 7, 1954. The headquarters of the meeting will be at Harrogate and, in place of the usual series of papers, there will be visits to the works of Imperial Chemical Industries Limited, at Wilton and Billingham, where safety methods and devices will be seen in practical operation.

The conference is intended to be of special interest to works managers, plant superintendents and works safety officials. Further particulars and detailed programmes may be obtained from the Association's offices, 86 Strand, London, W.C.2.

CENTENARY OF A FAMOUS SWISS FIRM

AMSLER INSTRUMENTS AND TESTING MACHINES

It is rather more than a century since James Amsler-Laffon invented the planimeter which still bears his name, and precisely a century since he started to manufacture it in a very small way at Schaffhausen, Switzerland. A mathematician and astronomer by training, James Amsler was a lecturer at the University of Zürich and then Professor at Schaffhausen College, but in spite of his academic qualifications, or perhaps because of them, he was quick to realise the commercial value of his invention and commenced to make it in his own workshop with the aid of two men. From this small workshop sprang the firm of Alfred J. Amsler and Company, Schaffhausen, which although not a very large organisation, has achieved a world-wide reputation for the high quality of its products, and will attain its centenary on June 12.

The Amsler planimeter is extremely simple to use although the theory of its action is based on higher mathematics. The user has merely to set the instrument to suit the scale, trace round any closed plane figure with a stylus fixed at the end of one of the arms of the instrument and read the area of the figure on the periphery of a small roller which rotates as the stylus is moved. The demand for the planimeter grew rapidly and its inventor went on to produce a series of precision mathematical instruments for various purposes, many of them embodying his basic idea of the integrating roller.

Instruments of this class were the principal products of the firm for two or three decades, but later the scope was extended to include hydraulic machines for testing materials. In 1886, James Amsler became acquainted with the inventions of the French physicist Amagat, who had constructed apparatus for determining the compressibility of liquids, involving the use of cylinders in which the fluid tightness of the piston depended only upon precision grinding, no cup leather being employed and oil being used as the pressure medium. This, of course, greatly reduced the friction in comparison with that due to leather packings and Amsler soon realised the advantages of Amagat's ideas in the construction of testing machines.

DYNAMOMETER CARS

At about this time James Amsler's son Alfred, who had served an extensive apprenticeship in his father's business, joined the firm, perhaps earlier than he might otherwise have done owing to the fact that his father's sight was beginning to fail. The son's gifts turned more in the direction of mechanical engineering and had the effect of shifting the manufacturing programme towards products of heavier calibre when he took over the management of the business at the turn of the century. His interest in hydrostatic problems led to the invention of the pendulum dynamometer, which is still one of the most accurate and reliable pressure-measuring devices used in testing machines. The introduction of hydraulic dynamometry into railway engineering, with the addition of integrating and differentiating instruments, led to the production of the dynamometer car, while the transition from the static to the dynamic method of testing materials was influenced by the introduction of the hydraulic pulsator which permits the production of a pulsating pressure in the cylinder of a testing machine.

The technical development and general growth of the business under the management of Alfred Amsler were greatly increased. The number of employees, in fact, reached the present level of about 300. It was at about this time, when Alfred Amsler was still in the prime of life and at the peak of his creative powers, when the business was flourishing and the value of his work had been acknowledged by the award of a number of distinctions, that the eye troubles inherited from his father attacked him, and being accompanied by increasing deafness, forced him slowly to withdraw from the management. His premature withdrawal doubtless expedited a change in the organisation which would have been brought about in any case by the rapid growth in technological knowledge. Hitherto, the history of the firm had been practically identical with that of the individual men at its head, but the whole field of technological knowledge had become so vast and was expanding so rapidly that it would obviously soon exceed the mental capacity of any individual. The work of one man had to give place to that of a team, including specialists in different branches of technology. Such a step naturally involved changes in organisation, as well as in the handling of technical problems, but the difficulties arising in this connection were soon overcome and technical successes followed in due course.

FATIGUE AND CREEP TESTING MACHINES

The manufacturing programme was greatly extended and those items which had already proved successful, such as testing machines, dynamometer cars and mathematical instruments, were improved and modernised. New products were introduced and perfected, many of them involving applications of the new science of electronics. One of these was the high-frequency Vibrophone – a fatigue-testing machine with all-electric control which is still being manufactured. The experience acquired with the integrating instruments employed on dynamometer cars was used in the design and construction of integrating apparatus for other purposes, such as the calculation of the trajectories of projectiles and the preparation of railway timetables. Some of these products have been introduced to the British technical public by descriptions published in our columns. In particular, the apparatus for calculating railway timetables was illustrated and described in ENGINEERING, vol. 174, page 717 (1952). Creep-testing machines with electronic temperature control may also be referred to in this connection.

Testing machines and dynamometers of all kinds now constitute the greater part of the firm's output, although special attention is still being given to the design and construction of mathematical instruments. Such activities, of course, require quality rather than quantity production and high-class design and workmanship are relied upon to maintain throughout the next century the high reputation achieved during the first. The present organisation, of which Dr. Werner Amsler, son of Dr. Alfred Amsler, became the head in July, 1941, is fully cognisant of the need to continue the modern tendencies which have been adopted, but will still adhere to the guiding principle which has served it well in the past: "To make things of lasting worth." Surely the original Amsler planimeter affords an excellent example of one of these "things."

Obituary

MR. F. M. G. DU-PLAT-TAYLOR

Consultant on Harbour and River Works

As briefly noted last week, the death of Mr. Francis Maurice Gustavus Du-Plat-Taylor occurred at his home in Kew, Surrey, on May 22. Mr. Du-Plat-Taylor, who was in the service of the Port of London Authority from 1909 until 1924, was the son of the late Colonel J. L. Du-Plat-Taylor, C.B., and was born in London on December 7, 1878. He received his general education at Farnborough School, Hampshire, and at Winchester College, and studied engineering at University College, London, from 1894 until 1896. He then served a year's apprenticeship under Sir Alfred Seale Haslam, at the Union Foundry, Derby, and, in 1897, became a pupil under Mr. A. G. Lyster, M.I.C.E., engineer-in-chief of the Mersey Docks and Harbour Board. Mr. Du-Plat-Taylor remained in the service of the Mersey Board until 1904, during which time he was employed on works connected with the new Brunswick river entrances and extensions to the Queen's and the King's Docks.

In May, 1904, he entered the service of the London and India Docks Company and, in the following year, was appointed resident engineer in charge of the East and West India Docks. He held this position until January, 1909, when he was transferred, as resident engineer, to the Tilbury Docks. When, in March, 1909, the Port of London Authority took over this undertaking, Mr. Du-Plat-Taylor was confirmed in his appointment. During the subsequent 15 years he was in charge of the construction of a reinforced-concrete cargo jetty in deep water on the River Thames and of extensions to the main and other docks at Tilbury.

On relinquishing his position in the service of the Port of London Authority in 1924, Mr. Du-Plat-Taylor commenced to practise on his own account. He was responsible for the design and for supervising the construction of sea walls and other defence works at many places on the coast, including Littlestone and New Romney, Kent. He also carried out land drainage works on the River Rother and at Lydd and Terrington. Moreover, his services as arbitrator and as court expert were frequently utilised.

Mr. Du-Plat-Taylor was elected a member of the Institution of Civil Engineers in 1919 and of the Institution of Mechanical Engineers in 1921. He was the author of many technical papers and other publications and had been awarded a Telford and a Manby Premium by the Institution of Civil Engineers.

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MR. E. F. LAW

Physical Metallurgist and Consultant

The death of Mr. Edward Fulton Law, which occurred suddenly at Weybridge, Surrey, on May 22, has also to be recorded. Mr. Law, who was senior partner in the firm of Riley, Harbord and Law, consulting metallurgists, Westminster, was born on October 10, 1877, and studied chemistry under the late Professor W. A. Tilden, D.Sc., F.R.S., at the Royal College of Science from 1894 until 1898. For the next four years he was a student of metallurgy under the late Professor Sir W. Chandler Roberts-Austen, F.R.S., at the Royal School of Mines. He duly obtained the Associateship of the School (A.R.S.M.) and was for a time a private assistant to Professor Roberts-Austen at the Royal Mint. In 1903 he commenced a private practice as a consulting metallurgist but subsequently joined Messrs. Edward Riley and Harbord in Westminster. Some time before the war of 1914-1918 he took up an appointment at the Openshaw Works, Manchester, of Messrs. Sir W. G. Armstrong, Whitworth & Co. Ltd., and remained there in charge of the production of armour plate until 1922. In that year he rejoined the late Mr. F. W. Harbord and his son, Mr. Vernon Harbord, as a partner in the firm which then became Riley, Harbord and Law.

On the outbreak of war, in 1939, Mr. Law was again called upon to help in the war effort and joined the late Sir Stanley Goodall in the Admiralty, at Bath. After the conclusion of hostilities he resumed his practice in Westminster and, as stated above, at the time of his death was senior partner in the firm.

Mr. Law became a member of the Iron and Steel Institute in 1908, served for a number of years on the Council and was elected an honorary vice-president in 1950. He contributed several important papers to the *Journal*, the first of which dealt with "Brittleness and Blisters in Thin Steel Sheets," read in 1906; "Non-Metallic Impurities in Steel," read in 1907, for which he was awarded a Carnegie Silver Medal; and "Application of Colour Photography to Metallography," presented in 1908. His microphotographs in the relatively early years of the science of metallography gave clear evidence of a high degree of manipulative skill. Mr. Law was also the author of the book *Alloys and Their Industrial Applications* first published in 1909, which remained a standard work on the subject for many years. His last paper to the Iron and Steel Institute dealt with "The Solidification and Cooling of Steel Ingots," and, written in collaboration with Mr. Vernon Harbord, was presented at the Autumn meeting of the Institute, in London, in October, 1943. Mr. Law was an original member of the Institute of Metals and among his contributions to its proceedings was a paper on the influence of oxygen on the properties of metals and alloys, presented in 1912.

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We regret also to record the deaths of the following:

MR. BENJAMIN HENRY HOVEY, at the Middlesex Hospital, London, on May 20, at the age of 56. He was managing director of Soag Machine Tools Ltd., and the Soag Machinery Co., Juxon Street, Lambeth, London, S.E.11.

MR. ARTHUR JOHN STURGEON, on May 26, at the age of 66. He was managing director of Foster Electrical Supplies Ltd., and a director of Foster Transformers Ltd., both subsidiary companies of Lancashire Dynamo Holdings Ltd. Mr. Sturgeon's association with the Foster organisation commenced in 1911.

MR. THOMAS COOPER, at Daldrishaig, Aberfoyle, Stirling, on May 28. Mr. Cooper was a former locomotive and carriage superintendent of the Bombay Baroda and Central India Railway, Bombay.

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PERSONAL

AIR COMMODORE L. R. S. FREESTONE, O.B.E., A.F.R.Ae.S., who has been Director of Armament Engineering, Air Ministry, since November, 1952, has been appointed to succeed AIR COMMODORE C. L. DANN, C.B.E., as Director (Air) of Technical Services, British Joint Services Mission, Washington, U.S.A., with effect from May 19.

MR. J. W. HENDERSON, B.Sc., M.I.C.E., at present chief engineer of the Hemel Hempstead Development Corporation, Westbrook Hay, Hemel Hempstead, Hertfordshire, is relinquishing his post this month to take up the appointment of chief executive officer of the Lagos Executive Development Board, Lagos, Nigeria.

SIR GEORGE BRIGGS, A.M.I.Mech.E., a director of Tube Investments Ltd., and a member of the Royal Ordnance Factories Board, has accepted an invitation to become a director of the BRUSH GROUP LTD. This is the new name of the parent company of the Brush Group; it has been changed from the BRUSH ELECTRICAL ENGINEERING CO., LTD. The latter is the name borne by the Group's subsidiary company managing the factory at Loughborough.

MR. J. PLOWMAN, general manager, in Scotland, of Dewrance and Co. Ltd., has been transferred to the London head office as chief executive assistant to the managing director. MR. D. HANDLEY is appointed manager of the Dumbarton Works.

MR. R. L. WALSH, Master Cutler, has been appointed by the President of the Board of Trade to be a member of the Council of Industrial Design.

MR. R. E. BURNETT, M.A. (Oxon.), A.M.I.E.E., A.Inst.P., has been appointed assistant to the general manager, Marconi's Wireless Telegraph Co. Ltd., Chelmsford, Essex, for special duties. He will retain, however, his responsibilities as manager of education and technical personnel and will remain principal of Marconi College. MR. E. R. L. LEWIS, M.A., A.M.I.E.E., has been appointed deputy manager, education and technical personnel; MR. R. G. HULSE, B.Sc., has been made deputy principal of Marconi College and director of studies and MR. J. LINDSAY SCOTT, Assoc.I.E.E., has been appointed chief of technical personnel recruitment.

MR. W. H. CARTWRIGHT has been appointed general manager of Stern and Bell, Ltd., makers of welded fabrications in steel, of Warstock-road, Birmingham, a member of the Triplex group of companies.

DR. E. MARSDEN, C.M.G., C.B.E., F.R.S., of New Zealand, has been appointed by the Council of the Royal Society to be the Rutherford Memorial Lecturer for 1954. He is delivering a series of lectures at university centres in South Africa. MR. D. M. BRINK, a graduate of the University of Tasmania, has been appointed a Rutherford Scholar for three years from October 1, 1954, to carry out research in nuclear physics at the Clarendon Laboratory, Oxford.

MR. G. M. SHEPLEY has been appointed secretary of Brooks Motors Ltd., Empress Works, Huddersfield, in place of MR. WILLIE MILLS, who joined the firm 50 years ago and has resigned the secretaryship owing to ill health. Mr. Mills, however, remains on the board of directors.

MR. H. S. CHAPMAN, treasurer of the London Transport Executive, 55 Broadway, London, S.W.1, retired on May 22 after 50 years of service and has been succeeded by MR. H. W. ALDRIDGE, A.M.Inst.T., formerly deputy to the treasurer.

MR. C. V. MILLER, for several years sales manager of Nu-way Heating Plants Ltd., Droitwich, has been elected to the board of directors.

It is announced that the address of MR. R. W. ALLEN, B.Sc.(Eng.), A.M.I.E.E., North-East area representative of Nife Batteries, Redditch, is now "Westbourn," Darras-road, Ponteland, Northumberland.

MR. R. G. HULL, manager of the Manchester sales office of the Northern Aluminium Co. Ltd., retired on June 1 and has been succeeded by MR. D. A. CORBETT-THOMPSON, formerly on the staff of the London Sales office.

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BUSINESS CHANGES

CUPODEL LTD., of Birmingham, specialists in hot-blast equipment for cupolas, have become associated, as from April 1, with KEITH BLACKMAN LTD. The registered office of Cupodel Ltd. is now Mill Mead-road, Tottenham, London, N.17, and the Birmingham office, 1294 Bristol-road South, Northfield, Birmingham, 31.

The address of the London office of RHODES, BRYDON AND YOUATT LTD., Stockport, Cheshire, is 76 Victoria-street, Westminster, S.W.1. (Telephone: VICtoria 0068-9.)

THE QUASI-ARC CO., LTD., Bilston, Staffordshire, as from June 1, are the licensees, in Great Britain and the Commonwealth (excluding Canada) for the Sigma shielded inert-gas metallic-arc welding process.

VICKERS-ARMSTRONGS LTD., Vickers House, Broadway, Westminster, London, S.W.1, announce the appointment of Richardson Agencies Ltd., 454 King-Street West, Toronto, 1, as their sole agents for the sale of strip-wound pressure vessels in Canada.

Following the statement, made last year, that CHARLES WINN & CO. LTD. were acquiring all rights in the Wynn Patent Straight-through diaphragm valve and were forming a subsidiary company to carry on and develop the sale of the valve, it is now announced that the whole range of valves of this type is being manufactured by the parent company at their works at Granville-street, Birmingham, 1. Additional manufacturing space has been provided in close proximity to the main works.

F. HAWORTH (A.R.C.) LTD., chemical engineers, Ramsbottom, Lancashire, have opened a London office at 40 Buckingham Palace-road, S.W.1. (Telephone: TATe Gallery 3861.) The office will be controlled by MR. D. P. HULBERT, a director of the company.

WESTINGHOUSE BRAKE AND SIGNAL CO. LTD., 82 York-way, King's Cross, London, N.1, in conjunction with BELLAMY AND LAMBIE (PTY.) LTD., of Johannesburg, who have been acting as the company's agents in South Africa for a number of years, have formed a new company under the title of WESTINGHOUSE BRAKE AND SIGNAL CO. S.A. (PTY.) LTD.

TRADE PUBLICATIONS

Pipework and Pipe Supports. Two booklets issued by Aiton & Co. Ltd., Derby, give details of various types of pipework and pipe supports for high-pressure and low-pressure work, and for land and marine installation. The supports described range from the simple saddle or roller to the Company's "Uniload" assembly, which balances the weight of the pipe and allows for unrestrained vertical movement.

Shaft Couplings. The Dominion Engineering Co., Ltd., Montreal, Canada, have sent us a pamphlet which describes in detail the design features and construction of their Gearflex couplings. The gear type construction used allows unrestricted axial movement of the shafts within suitable limits and their flexibility ensures that bending stresses and bearing overloads are prevented. The coupling is of steel construction. Sizes are standardised and couplings for shafts from ½ in. diameter to 10¾ in. diameter are available from stock.

Acoustic Controller. Standard Telephones and Cables, Ltd., 63 Aldwych, London, W.C.2, have issued a leaflet describing their acoustically operated controller for a crushing mill feed. The noise made by the mill varies with the amount of material in it, and the controller detects any noise change and adjusts the feed accordingly.

Supervisory Control. A hand-book published by Standard Telephones and Cables, Ltd., Oakleigh-road, New Southgate, London, N.11, describes methods of centralised supervisory control and the components used. Typical circuit diagrams are given.

Self-regulating Alternators. Self-regulating alternators with outputs up to 15 kVA at 1,800 r.p.m. are described in a leaflet issued by the Electro Dynamic Construction Co., Ltd., St. Mary Cray, Kent.

Electric Drives for Paper-Making Machines. Harland Drives, Ltd., 20 Park-street, London, W.1, have sent us a well-illustrated pamphlet giving details of the electric drive they manufacture for operating paper-making machines.

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BOOKS RECEIVED

Britain's Railways Today. Edited by JOHN ST. JOHN. *The Naldrett Press, Limited*, 91-93 *Baker-street, London, W.*1. (15*s.*)

The Microscopy of Metals. Lectures delivered at a Refresher Course of the Institution of Metallurgists, 1953. *The Institution of Metallurgists*, 28 *Victoria-street, London, S.W.*1. (15*s.* 6*d.*)

Directory of International Scientific Organizations. Second edition. *United Nations Educational Scientific and Cultural Organization*, 19 *Avenue Kléber, Paris* (16*e*). (650 francs); and *H.M. Stationery Office, Kingsway, London, W.C.*2. (13*s.* 6*d.*)

The Steel Skeleton. Vol. I: Elastic Behaviour and Design. By J. F. BAKER. *Cambridge University Press*, 200 *Euston-road, London, N.W.*1. (42*s.*)

A Text-Book of Metallurgy. By A. R. BAILEY. *Macmillan and Company, Limited, St. Martin's-street, London, W.C.*2. (30*s.*)

Technical Reports of the British Electrical and Allied Industries Research Association:

Flameproof Electrical Apparatus: Flanged Joints, One Inch and One Half-Inch in Radial Breadth, in Atmospheres of Pentane Vapour and Air. By H. ROBINSON and H. L. WILLIAMS. No. G/T291. (10*s.* 6*d.*)

Ferromagnetic Domain Processes in Single Crystals of Silicon Iron. By D. H. MARTIN. No. N/T65. (4*s.* 6*d.*)

A Note on the Use of Electrode Potentials for the Estimation of Corrosion due to Dissimilar Metal Contact. By G. MOLE. No. O/T11. (7*s.* 6*d.*)

The Impedance of Steel Conduit used as an Earth-Continuity Conductor. By A. BUTTERWORTH, L. GOSLAND and G. F. SHOTTER. No. V/T111. (12*s.*)

Testing of Earth-Continuity Conductors. By G. F. SHOTTER and N. ELLIOTT. No. V/T114. (10*s.*)

The E.R.A. Network Analyser, March, 1954. No. V/T122. (9*s.*)

Offices of the Association, Thorncroft Manor, Dorking-road, Leatherhead, Surrey.

Bergbaumechanik. Lehrbuch für bergmännische Lehranstalten. Handbuch für den praktischen Bergbau. By J. MAERCKS and G. JUNGNITZ. *Springer-Verlag, Reichpietschufer* 20, *Berlin, W.*35. (36 *D.M.*)

OLD ENGINES IN CORNWALL

SUMMER MEETING OF THE NEWCOMEN SOCIETY

About 40 members and guests attended the summer meeting of the Newcomen Society which was held at Falmouth, Cornwall, on May 27 and 28. The first visit on May 27 was to Redruth, where the party inspected Murdock House, the residence for over 20 years of William Murdock, while he was the Cornish agent of Boulton and Watt. The house is now owned by a local trust and is used for adult educational purposes.

From Murdock House the party proceeded to East Pool Mine, about two miles distant, where they were received by Mr. A. Treve Holman, O.B.E., M.I.Mech.E., chairman of the Cornish Engines Preservation Society. The Society are the owners of the 90 in. by 10 ft. Cornish engine at the mine, and are to preserve it when it ceases work in the near future. At present the engine, which was built by Harvey and Company, of Hayle, Cornwall, in 1893, is pumping water to assist in draining the nearby South Crofty Mine, but electrical equipment is being installed to take over this duty. The engine draws from 1,034 ft. It is the largest of the Cornish engines still left in the county, though the oldest still at work, and in many respects the most interesting, is Robinson's engine at South Crofty Mine, which the party next visited. This engine, which is in its hundredth year of service, was designed by Samuel Grose, a pupil of Richard Trevithick, and built by Sandys, Vivian and Company at Hayle in 1854. It has a bore and stroke of 80 in. and 10 ft. 4 in., respectively, and is pumping from 2,021 ft. The engine has several features peculiar to its designer, including an arrangement of valves which makes it an early form of uniflow engine. Robinson's engine, like that at East Pool, is due to cease work as soon as the electric pumps are in operation.

In the afternoon a visit was made to Penponds, near Camborne, where Trevithick's house was seen. Richard Trevithick, the greatest of all the Cornish engineers, was born at Pool, near to Robinson's engine, and the party had seen earlier in the day the tablet marking the site of his birthplace. As a small child he was taken by his parents to Penponds, and he lived there until he reached manhood. The Penponds cottage was restored a few years ago after becoming practically derelict, and is now the property of the Cornish Engines Preservation Society, which lets it to a tenant and makes provision for public access. It is hoped to equip one room in the cottage in due course as a Trevithick museum. The party next proceeded to Camborne, where the president of the Newcomen Society, Mr. Rex Wailes, F.S.A., M.I.Mech.E., placed a chaplet on the Trevithick memorial. The memorial is a bronze statue of the inventor and faces, appropriately, Camborne Hill, up which on Christmas Eve, 1801, Trevithick's road locomotive made its historic journey.

Mr. A. T. Holman then conducted the party across the road to the Holman Museum, where the principal exhibit was the Rostowrack engine, a Cornish rotative engine of 1851. It was removed from the Rostowrack china-clay mine, near St. Austell, in 1953 and installed in the Museum, where it is arranged to run on compressed air. A detailed description of the engine, and of the other engines seen by the Newcomen Society, appeared in ENGINEERING of September 11, 1953 (page 339), when the Rostowrack engine was formally handed over to the Cornish Engines Preservation Society by Lord Falmouth. A pendulum counter, which was formerly the property of the late Mr. W. A. Michell, the last of a long line of Cornish mining engineers, has recently been mounted on the beam of the Rostowrack engine, and it recorded that 286 strokes were made during the Newcomen visit. The Holman Museum contains a large collection of exhibits of mining and engineering interest, including two models of man-engines, which were used at one time to raise and lower men in the mines.

In the evening of May 27 the annual dinner of the Newcomen Society was held at the Falmouth Hotel, and the Society welcomed as guests the Mayor and Mayoress of Falmouth, Surgeon Commander J. L. Lean, R.N. (Retd.) and Mrs. Lean. After the loyal toast, and toasts to the memory of Thomas Newcomen, Richard Trevithick and William Murdock, Mr. A. K. Hamilton Jenkin, M.A., the Cornish historian, delivered a short address on Cornish mining history. Mr. Jenkin reviewed the geology of the district, and pointed out that tin was first produced in Cornwall from alluvial deposits. When mining first started is not known, but the history of the industry extends back many thousands of years. By the time of Elizabeth I, the alluvial deposits were showing signs of exhaustion and deep lode mining had started. Deep mining brought drainage troubles and Cornwall became one of the earliest fields of experiment in pumping. The engines of Savery, Newcomen, Watt and others were used, and from them developed the celebrated Cornish engine, which was for 25 years supreme in the field of mine drainage. The mining industry underwent many changes in its long history, and there were periods of great prosperity alternating with severe depressions, but mining in one form or another had continued to the present day. To-day, owing to the competition of overseas alluvial deposits and the high cost of working the deep Cornish mines, the industry was small compared with former days and only three mines were still at work. Mr. Jenkin concluded by saying that there was a great deal of tin and other minerals still left in Cornwall but that no development could be expected until there were radical changes in the present method of mining taxation.

On May 28 the party left Falmouth by motor coach to visit the St. Austell district, passing, en route, the old Perran Foundry, where many of the most famous of the Cornish engines were built. The foundry operated in the period 1791-1879. It is now a flour mill but much remains of the original buildings, including a cast-iron archway at the entrance. Near St. Austell the party inspected Goonvean china-clay pit and its Cornish pumping engine. Goonvean clay pit is one of the deepest in Cornwall, and the engine, a 50 in. by 10 ft. steam stroke and 9 ft. shaft stroke Harvey product, raises china clay suspended in water from a depth of 365 ft. After lunch a visit was made to Lanivet, near Bodmin, where a stamping mill, now derelict, was seen. The stamps are of the traditional Cornish type, having wooden lifters and cast-iron cam barrel. The party then proceeded to Chyverton, Zelah, the residence of Mr. and Mrs. A. Treve Holman, where they were entertained to tea and shown round the house, which dates from 1783, and the gardens. The evening was spent at Falmouth Library, where Miss R. Beckett, A.L.A., the Borough Librarian, had arranged a special exhibition of books, drawings, prints and models of Cornish mining and engineering interest.

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CONTROL OF QUALITY IN WROUGHT METALS: ERRATA

In our report on the discussion of the symposium on "The Control of Quality in Working Wrought Metals," held during the recent spring meeting of the Institute of Metals, the name of one of the speakers, on page 650 of our issue of May 21, given to us as Mr. A. G. Adlington, should have read Mr. R. W. Elkington, of Aluminium Laboratories Ltd., Banbury, Oxfordshire. Moreover, the names of the two research workers in America and Canada are Stroup and Barker and not as stated in our report.

BRITISH IRON AND STEEL RESEARCH

Among the more promising research projects of the British Iron and Steel Research Association is that involving the continuous casting of steel. Some time ago, it was reported that a satisfactory casting technique had been developed at the Battersea Laboratories of the Association and that a pilot plant for commercial operation was envisaged. It is stated in the recently-issued tenth annual report of the Association, which covers the year ended December 31, 1953, that a Development Group of 12 firms on continuous casting had been formed. This Group is sponsoring a two-strand continuous-casting plant of B.I.S.R.A. design now being built at the works of William Jessop & Sons, Ltd.

CONTINUOUS CASTING

The pilot plant has been designed to produce 35 ft. of 4-in. square billets from each strand from a furnace charge of about 1½ tons. The continuous casting of high-speed steel is to be attempted first. Parallel with the installation of this plant, experiments have been carried out at the Sheffield and Battersea Laboratories to improve certain aspects of the process. Pouring experiments with 10-cwt. charges of steel have shown that it is practicable to pour this quantity of steel, without leaving a skull in the ladle, through a $\frac{5}{16}$-in. nozzle in a gas-heated tundish at the rate of 3 tons an hour, this being the rate required for single-strand casting. With the decision to erect a two-strand plant, lip-pouring experiments in conjunction with a T-shaped runner to teem uniformly into two moulds have begun and the early results are encouraging. At the Battersea Laboratories, experiments with high-speed steel have shown that the friction between steel and mould is much greater than for plain-carbon steels and that the average rate of heat transfer from the steel to the mould is also higher. Lubrication experiments will be necessary to arrive at a satisfactory lubricating technique and to decide upon the most suitable lubricant.

In addition to work in this country, a special arrangement has been made with an American company to operate the Association's patents in that country. Moreover, further negotiations are in progress with plant manufacturers for the development of continuous casting methods in Sweden and elsewhere.

There are altogether some 200 projects in the current research programme of the Association, but Captain H. Leighton Davies, C.B.E., chairman of the Council, emphasises that there are many others that could well be started if sufficient funds were available. In particular, he states, there is a special need to intensify research on the design of steelworks plant as it is felt that the industry for too long, has been dependent upon American design.

LOW ALLOY STEELS FOR RESISTING CORROSION

In the corrosion section a research into the resistance of low-alloy steels in various environments has been completed and a report is being published in the *Journal* of the Iron and Steel Institute. The principal conclusion is that under conditions of atmospheric exposure the corrosion rate of steels containing small percentage additions of chromium, copper and nickel is not more than one-third of that of ordinary mild steel, When immersed in sea water, small additions of alloying elements are not so beneficial; the corrosion rate, however, is halved by the addition of 3 per cent. of chromium and there are indications that aluminium and beryllium additions may be of value.

Creep tests have continued to provide design data for steels which will be used for components carrying steam at temperatures of up to 1,050 deg. F. (566 deg. C.) and at pressures of up to 1,500 lb. per square inch in power plants which will be commissioned in the near future. The tests are being carried out at stresses of the same order as those expected in the components concerned but, in order to accelerate the work, the testing temperatures, in most cases, are in excess of those expected in the power plants. Tests have been carried out at temperatures between 500 deg. and 750 deg. C., the exact temperature range depending on the steel and the component. Further tests at lower temperatures but at higher stresses are contemplated. The investigation is being conducted on specimens machined from actual components and the programme includes tests on steam pipes and superheater tubes in the ferritic 2·25 per cent. chromium, 1 per cent. molybdenum steel and the austenitic 18 per cent. chromium, 12 per cent. nickel, 1 per cent. niobium steel. Tests are also being made on steam pipes made in molybdenum-vanadium steel.

LIFE OF BASIC REFRACTORIES

Collaborative work with the British Ceramic Research Association has continued under the guidance of the Joint Refractories Committees. The position with respect to the "all-basic" open-hearth furnace has been ambiguous for some time. Only in one case, that of a furnace at Bilston, have the lives of expensive roofs been long enough to show a clear economic advantage over silica construction. In furnaces at other works, lives have been such that there has been sometimes an advantage and sometimes a disadvantage in the use of basic construction. A programme is in hand to develop improved bricks and a study is being made of the environmental factors which influence the life of a basic refractory.

SPEED OF FURNACE CHARGING

The operational research section of the Association has been increased and is investigating a wide variety of problems. The charging of open-hearth furnaces, especially where scrap forms a large proportion of the charge, raises questions of the most economic numbers of cranes, bogies, charging machines and other plant required under given conditions. Detailed studies, so far, have been completed at three steelworks, primarily to solve specific problems connected with the need to reduce delays in furnace charging and to cut out superfluous operations in order to increase production. The handling, preparation, and movement of scrap from stock to furnace have been studied. At one steelworks the management required a forecast of the facilities which would be needed ultimately to ensure the scrap supply to a larger number of furnaces than were in use at the time. Recommendations were put forward and have been adopted. At the other two works, transport and handling facilities were severely taxed because of increased furnace capacities, and delays to furnace charging were being experienced. Accordingly, suggestions were made for modifying the storage policy and for improving the supply services.

SOCIAL CONSEQUENCES OF IRON AND STEEL*

By R. G. Lyttelton†

The earliest iron remains are now accepted as being of meteoric origin. Meteoric iron was known over a considerable area of the ancient world. This is made evident by the traditional name for iron in many languages, which, when translated, means "something hard from heaven." A pyramid inscription of 2500 B.C. calls it "metal of heaven," while a Hittite text eleven hundred years later mentions "black iron from the sky," thereby indicating the colour of the surface of meteoric iron. The Aztecs of Mexico produced knives and daggers from meteoric iron, which they valued far above their gold. In answer to their Spanish conquerors as to where they obtained these pieces of metal they said they were gifts from the gods and came from the sky.

It is curious that in the Western world for many centuries meteoric iron was dismissed as mythical. It was not until April, 1803, when a shower of meteorites was observed at L'Aigle in Normandy by some thousands of people, that the celestial origin of this material was generally accepted. Meteoric iron contains anything from 3 to 7 per cent. of nickel, as well as traces of cobalt and other elements, which no doubt explains why some knives, beads, etc., made of it retaining their original form have been discovered after lying in the ground for some thousands of years.

The earliest known iron tool is a sickle discovered in the temple of Karnak and made in about 3000 B.C., and it is of interest that it was not until the 1890's, with the discovery of alloy steels, that steel of similar properties was produced by man – 5,000 years after the time when it was first used.

The beginning of the Iron Age is generally fixed at about 1400 B.C., and the earliest centre of production is now considered to have been Asia Minor, between the Caucasus and the Taurus Mountains, where the Hittites used lake and bog ores as well as iron sand, and wood for smelting. The products of this settlement were no doubt carried west, and the famous cemetery of Halstadt produces evidence of the iron industry of Carinthia in 1000 B.C. It may be a matter of surprise that the Iron Age did not open earlier, when it is remembered that every ton of the earth's crust contains 1 cwt. of iron of a varying degree of purity: but the temperature required for reducing it from the ore is so much greater than in the case of copper and bronze that when iron ore was first subjected accidentally to the temperatures of the camp fire it was only reduced to the plastic state and was thought to be a malleable stone. The accidental appearance of this metal would need to happen many times before primitive man could notice it or connect the effect of heat with the occurrence of fusibility, and even then deduction from effect to cause might not be made.

It seems certain that metal working was introduced into Britain by immigrants from the Continent. Iron in the plastic state when hammered into shape by the squeezing out of slag revealed itself as a metal. From the primitive furnace – simply a hole in the ground in which alternate layers of ore and charcoal

* Presidential Address to the Iron and Steel Institute, delivered on Wednesday, May 26, 1954. Abridged.

† Director, Guest Keen Iron and Steel Company, Limited, and London Manager of Guest Keen and Nettlefolds, Limited.

were laid – was developed the furnace made of puddled clay as a structure above the ground.

This method of producing iron persisted in Europe until the middle of the fourteenth century, the only advance being in the gradual enlargement of the furnaces. The iron produced was a plastic lump, the furnaces being called "bloomeries" from the Anglo-Saxon "*bloma*" – a lump. It was purified by reheating and continual hammering to squeeze out the slag and was, in fact, what is now known as wrought iron. This iron was too costly for general use except in a very limited way, mainly for service in war, and iron pots, spits, and frying pans, in the reign of Edward III, even in the fourteenth century, were classed among the Crown Jewels, though these may have been of special and elaborate fabrication. The frequent heating in charcoal fires for forging carburised the iron and occasionally produced weapons such as swords which, when quenched for cooling, became tempered steel. Thus arose the legends of swords with miraculous powers possessed by such heroes as King Arthur and Charlemagne.

With the development of goatskin bellows operated by the feet of the workers, an artificial draught and a much higher temperature were obtained.

BRITISH IRON INDUSTRY

It was not until the application of the water wheel to operate the bellows, *ca.* 1340, that cast iron was produced in Great Britain, almost certainly first in Sussex, where at Burwash there is a cast-iron tomb bearing an inscription in Lombardic characters of the fourteenth century. Some historians now ascribe this grave-slab to the sixteenth century. There was thus a period of 2,500 years between the discovery of sponge iron and the art of casting it. The iron industry in Britain developed largely in Kent, Surrey, and Sussex, owing to the presence of hardwood forests which provided the charcoal. The foundry industries of these counties, and of Sussex in particular, became famous for the production of cast-iron cannon, for which there was a considerable export trade.

In the early years of the eighteenth century Abram Darby, at Coalbrookdale, was experimenting with the use of stone coal in the production of iron. He succeeded in producing iron in a blast-furnace by first reducing the coal to coke. Darby's blast-furnace in its fundamental principles was identical with the modern furnace. The blast was created by the use of bellows driven by a water wheel, and the use of the more porous coke made possible a more powerful blast and the air could be forced to the centre of the stack. This discovery was an historic event and, as Rickard's well-known aphorism reads, "the marriage of coal and iron at which Abram Darby officiated as High Priest gave birth to the industrial revolution." This is no exaggeration.

The scale of the industry at this time may be judged from the fact that the total production of iron in Britain in the year 1740 was only 17,350 tons – the second highest production in the world, Sweden being the highest producer, thanks to the large resources of timber surrounding her magnificent ore fields and to the genius and character of her people. The use of coke for the production of iron spread to the iron and coal centres of the country, and by the end of the century was fairly general. The iron industry was transferred from the wooded districts to the Black Country, Yorkshire, the coal districts of Wales, the Forest of Dean, the North East Coast, and to Scotland.

The full benefit of Darby's method could not be obtained by the inefficient water-driven bellows then available. Watt developed his improved steam engine in 1769. This development was much facilitated by Darby's invention, which provided cast iron at a reasonable price and in substantial quantity. Wilkinson's inventions of the cupola, and accurate cylinder boring, made iron castings available to the engine and machinery builders. Conversely, the engines provided by Watt rendered possible the application of increased power for blowing and mechanical power for forging. The application of power to what had previously been handicrafts, particularly in the textile industry, was the beginning of the Industrial Revolution.

INDUSTRIAL DEVELOPMENT

One of the characteristics of the Industrial Revolution was the rapidity with which inventions that proved complementary in the development of the industrial system followed one another so closely. While Abram Darby was perfecting the smelting of iron with stone coal, Huntsman of Sheffield in 1740 perfected the production of steel of uniform quality by melting blister steel in clay crucibles placed in coke furnaces. The fundamental character of his invention was the production of crucibles that would withstand the high temperature required.

A century later, Heath and Mushet introduced the use of alloying elements in the form of manganese and tungsten to toughen the steel. Cort invented the grooved rolling mill in 1783 and the process of puddling iron in 1784. In 1828, James Beaumont Neilson heated the blast to the iron furnaces and thus decreased the consumption of coke from 8 to 5 tons per ton of iron produced. However, until Bessemer perfected his pneumatic process barely 100 years ago steel was produced only in small quantities. A year after Bessemer made known his invention, Siemens invented the open-hearth process in England. In 1879, Thomas and Gilchrist introduced the basic lining for steel furnaces and made possible the basic Bessemer process which created the steel industry on the continent of Europe, particularly in the valleys of the Saar and the basin of Briey, where lay abundant deposits of iron ore previously unusable because of its high phosphorus content.

The iron and steel discoveries and inventions of Darby, Huntsman, Cort, Heath, Mushet, Neilsen, Bessemer, Siemens, Thomas, and Gilchrist were paralleled by a brilliant galaxy of inventors connected with the manufacturing industries, resulting from the application of power to handicrafts, only made possible by the production of iron and steel in quantity.

Thus on the basis of the two natural resources which Britain possesses in quantity – coal and iron – did she gain the industrial leadership of the world for a century.

COMMUNICATIONS

The opening of the Stockton and Darlington Railway in 1825 was the birth of a social and economic revolution which, by the removal of the limitation imposed by distance, permitted the assembly of people and materials promptly and economically wherever they were required. Production was simplified and markets extended so that costs were reduced, employment increased, and the standard of life raised ultimately for the nation as a whole.

George Stephenson improved the locomotive and made it practicable for continuous service. The rails for the Stockton and Darlington railway, 26 miles long, and used for mineral traffic, were made of wrought iron and weighed 28 lb. per yard.

The early railways were of necessity based on wrought iron as the only suitable material available until 1856, when the first Bessemer steel rail was rolled at Dowlais Works.

In 1850 the total railway mileage in the world was 18,000. By 1860 this had increased to 63,000; in 1870 to 127,000; and in 1878 to 206,000, of which the United Kingdom possessed 17,000 miles. To-day, the figure for the whole world is 800,000 miles, of which Great Britain possesses 51,000 with 3,000 more of single track in Ireland.

Until steel rails became available, the output of wrought iron rails in Britain was 750,000 tons per annum. Ramsbottom, the civil engineer of the L. and N.W. Railway, said that wrought-iron rails lasted only four months in service. After laying one rail of the main-line track at Chalk Farm with steel, and the other with wrought iron, he found that the wrought-iron rail had to be changed 23 times to once for steel. Steel thus became the material for railway track. The expansion of railways throughout the world was so rapid that until 1881 more than half the steel production of the world was used for railway track.

Fortunately for the producers of wrought iron, the shipbuilders were replacing timber with iron, first in composite ships of wood and iron and then with vessels wholly of iron; this for a time made good the loss of the railway market.

The advent of steel and the development of steam power gave a tremendous impetus to shipbuilding. In 1848 British-owned tonnage of wood and composite ships was 5,278,000 tons; 100 years later, in 1947, it was 21,549,000 tons, in spite of war loss, and to-day it is 22,300,000 tons. Neither railways nor shipping would be possible on the present scale without steel.

The present century is notable for the great advance in alloys, both ferrous and non-ferrous. The stainless group of alloy steels, discovered by Brearley in 1913, apart from their use for cutlery, ornament, and structures, have made an invaluable though indeterminable contribution to the rising standard of life; indeterminable because they have made possible many manufacturing processes the products of which contribute much to the production and preservation of food, medicine, and personal comfort.

The advance in the production of alloys has also had a profound influence on the development and application of mechanical power.

STRUCTURES

While bridge building has been much facilitated and stimulated by the development of iron and steel in suitable forms, bridges have not had the same dominant social influence as mechanical power, railways, and shipping. They have made communities, sources of materials, and foodstuffs more accessible, but without them alternative means of communication – although often much longer and more costly – are in most cases available.

RESEARCH

During the last half of the nineteenth century, and particularly in the last quarter, the speed of invention in manufacturing processes received a remarkable impetus as a result of the discovery of the fundamental scientific principles on which industrial processes depend. Most of these had been devised empirically by trial and error.

Research has now become recognised as an essential part of the equipment of industry: the steel industry was one of the first to establish research laboratories in the larger works. In 1924 the British Iron and Steel Federation set up a co-operative Research Committee with which the Department of Scientific and Industrial Research and this Institute were associated. This has now developed into the largest co-operative industrial research organisation in Britain, still in collaboration with the D.S.I.R. and the Iron and Steel Institute.

GROWTH OF POPULATION

The increase in population of the United Kingdom from 1740 to the present time could not have been supported without the development of transport and productive machinery, and the application of mechanical power to manufacturing industry and agriculture, which steel alone made possible. The population of England and Wales in 1066 has been computed at between 1½ and 2 millions; the iron production was then insignificant – possibly a few hundred tons. It rose to about 50,000 tons in the year 1760 and then increased rapidly (as a result of the application of stone coal to iron smelting, and the Industrial Revolution) to 4,000,000 tons in the year 1860. The first national figures available for steel production in the United Kingdom were 160,000 tons in 1869 – iron production in the same year being 5,450,000 tons. Steel production for the present year has been in recent months at the rate of 18½ million tons per annum.

The C.I.G.R.E. Meeting in Paris (continued from page 685)

HIGH-TENSION ELECTRIC POWER TRANSMISSION

Two papers on high-voltage direct-current transmission, which were not included in the original programme, were presented by Swedish engineers at the 15th meeting of the Conférence Internationale des Grands Réseaux Electriques à Haute Tension. The authors of the first of these were Mr. B. G. Rathsman and Mr. A. U. Lamm, who gave an account of the development work on "The Gotland High Voltage Direct-Current Transmission Scheme." In 1953, the load in the island of Gotland was about 16 MW and the annual consumption 69 million kWh. It was supplied from a steam power station, but owing to the high cost of fuel the tariffs were appreciably higher than on the mainland. A plan was therefore devised for transmitting high-voltage direct current to supplement the existing plant.

The installation consisted of a rectifier station near Västervik on the mainland, where the 130-kV 50-cycle current was converted into 100-kV direct current. This was transmitted through a single-core cable, 100 km long, at both ends of which were smoothing devices to limit the current surges. The direct current was inverted to alternating current at 10 kV in a station near Visby and was then fed into the 30-kV network of Gotland.

The reactive power required by the network and the inverters (about 15 MVA and 9 MVA, respectively, at the present time) was obtained from a 10-kV 30-MVA synchronous condenser. Operation was normally supervised from the Visby inverter station from which the Västervik station could be controlled through a radio link.

CIRCUIT THROUGH THE SEA

The return circuit was through the sea with electrodes both on the island and the mainland. These electrodes were situated about 10 km from the cable and were connected to the converter stations by overhead lines, which were provided with protective devices where telephone or other lines were crossed. These devices were not earthed, since if an electrode fell on them the direct-current leakage to earth might cause corrosion.

On the Västervik side where the electrodes operated as anodes all metals had to be avoided. The electrodes, of which there were twelve, were therefore of magnetite or graphite of the standard furnace type, each being about 1 m. long and 120 mm. in diameter. The current was supplied to them through a plastic-insulated conductor, which was connected to the electrode through a water-tight cap of Neoprene. Each electrode was mounted on a wooden sledge, which was enclosed in a perforated clay pipe to protect it from mechanical damage. They were placed about 2 m. apart in an off-shore basin. At Visby, where the electrodes acted as cathodes and there was therefore no risk of corrosion, bare copper wires were used. These were laid to about 350 m. from the shore and connected to the overhead system by an armoured cable.

The six-valve rectifiers and inverters were of the semi-pumpless air-cooled type with two anodes connected in parallel through a distributor. The negative grid voltage was obtained from a metal rectifier and the positive grid-control impulses through a transformer and a "control-impulse transmitter." This transmitter was, in turn, controlled by a low voltage derived from a "phase-angle producer" and an automatic regulator which were adjusted in accordance with the programmes for both rectifier and inverter operation.

INVERTER OPERATION

The phase-angle producer for inverter operation was supplied by, and was solely dependent on, the commutation voltage of the valve to which it was connected and on the input direct-current. This device consisted of transformers, metal rectifiers and reactors and ensured that the commutation range of the valve was constant irrespective of the magnitude and assymmetry of the alternating-current voltage and of the direct current. Normally it controlled the grid of the inverter, so that the best combination of high power factor and safety were obtained. The voltage of the alternating-current system at the receiving end was regulated by adjusting the excitation of the synchronous condenser. The direct-current voltage at the inverter terminals was therefore a function of the load on the receiving alternating-current system.

Power regulation was effected by the rectifiers at the transmitting end, the aim being to maintain constant frequency in Gotland. Any deviation from this frequency was adjusted by a device on the Gotland side. When the inverters were operated in parallel with the steam station on the island the direct current was transmitted at a constant value, although operation at constant frequency was also possible.

One converter was ready at the beginning of 1954, but the synchronous condenser was not available until the end of March. The commutating voltage for the inverter had therefore to be obtained from the steam station on the island, which was only large enough to supply a light load. On March 7, however, about 2,000 kW was transmitted, and a few days later a static converter was connected to the 10-kV bus-bar in the inverter station and the load raised to 4,000 kW.

After a breakdown in the cable, 34 km. from Västervik, had caused some delay, the synchronous condenser was brought into operation and since April 12 the system had been transmitting 10,000 kW.

100-KV DIRECT-CURRENT CABLE

The 100-kV direct-current cable used in the Gotland scheme was described by Mr. B. Bjurström and Mr. R. Johansson (Sweden). It was designed to carry 200 amperes and to be capable of withstanding both impulse and direct-current tests at 425 kV. The cross section of the conductor was 90 sq. mm., which was unduly large for the current, but if a smaller section had been chosen thicker insulation would have been necessary. Polyethylene was used as an insulating material and was impregnated with high-viscosity oil. Two thin lead sheaths were employed to increase the flexibility and were covered with polyvinyl-chloride tape. The portion of the cable laid in deep water was armoured with galvanised steel wires 4 mm. in diameter, while additional layers of galvanised steel wire 6 mm. in diameter was used on the shore ends. The sea cable had an overall diameter of 50 mm. and weighed 8·4 kg. per metre, while the shore cable was 70 mm. in diameter and weighed 15·6 kg. per metre.

EXTRA-HIGH-VOLTAGE TRANSMISSION

Only seven papers were presented on the subject of alternating-current transmission at extra high voltages, two of which we have already dealt with on page 609, *ante*. A paper by Mr. D. P. Sayers, Mr. F. J. Lane and Mr. J. S. Forrest summarised the progress that had been made on the British 275/300-kV system during the past two years, and recorded that the first experimental section, comprising a 40-mile line of single-circuit twin 0·175 sq. in. steel-cored aluminium conductor, had been in operation since July, 1953. Contracts had been placed for about 1,250 circuit miles of double-circuit line out of the total of 2,457 circuit miles required for the 1960 scheme. Up to October, 1953, about 2,000 tower positions had been determined, 1,000 foundations installed and 500 towers erected.

The economic justification of the scheme was that at least 10 per cent. more generating plant would be required to meet the national load if there were no inter-connection between areas. The capital cost of the interconnection scheme was £64 million, whereas the cost of only 5 per cent. more generating plant, including additional local transmission lines, would be about £110 million.

NATIONAL DEVELOPMENTS

A report by Mr. P. Sporn (United States) on "Alternating Current Transmission at Extra High Voltage," contained some useful information regarding the developments that had taken place in this direction in the various member countries. In Sweden, 570 circuit miles of 380-kV line were in operation in 1952 and an additional 300 miles had been added during 1953. By the end of 1956 it was expected that there would be 1,670 circuit miles in service at this voltage and an additional 200 miles by 1958.

In France, the highest rated voltage at present was 230 kV, but 730 miles of line of two-circuit construction were being built, which could be converted to carry a single-circuit 380-kV "bundle" conductor. This practice was being continued. The highest voltage in Germany was 300 kV and a 150-mile line had been energised at that pressure in 1952. During the past few years, 220-kV lines had been constructed with a two "bundle" conductor for later operation at 380 kV. A total of 328 circuit miles of such line had been built or were under construction or planned.

In both Italy and Switzerland the highest voltage in use was 220 kV, but some of the more recent lines were suitable for 380-kV operation. A 300-kV line was being built in Canada and others operating at the same voltage were being designed. A 345-kV line was also being built.

A 287-kV system had been in operation in the United States since 1937 and now comprised about 825 miles of single-circuit line. At the present time, a higher voltage system was being built in the east central part of the country. This comprised 100 miles of 330-kV circuit, which were being operated at 132 kV. By the end of 1956, 1,354 miles of 330-kV line would be in operation. Other transmission systems for operation at 300 kV and 345 kV were being built or under consideration; and 440 kV was being investigated by one company.

It was understood that 330 kV had been adopted in Australia, and Japan was working on a 275-kV system. No report of an authentic nature had been received since the last conference on extra-high-voltage lines in Russia.

FUTURE TRENDS

Summarising the position, Mr. Sporn said that during the 75 years the electric power industry had been in existence voltages had increased from 100 volts to 380 kV. The information given above showed that more than 6,600 miles of lines operating at between 275 and 380 kV were either built, projected or planned.

The demand for additional electric power in practically all industrially-expanding nations was so great that it could confidently be expected that alternating current extra-high voltage systems would become quite commonplace in the relatively near future. It was possible, in fact, that even higher voltages would be needed and there seemed no doubt of our ability to develop their use from the technical knowledge now available.

It was of particular interest to note that the manufacturers of transformers, circuit-breakers and other switchgear had been keeping pace with the trend towards higher transmission voltage so that equipment would be no barrier in the step to the next higher voltage. Circuit-breaker rupturing capacity had been increased from 5,000 and 10,000 MVA to the 25,000 MVA which was required by the heavy concentration

of power at the highest voltage available at present.

CIRCUIT-BREAKER DEVELOPMENT

The interest at present shown in circuit-breaker design and performance was indicated by the fact that no less than 14 papers were presented. Among these, was one on "The Field Testing of 380-kV Circuit-Breakers," in which Mr. G. Jancke and Mr. U. Sandström (Sweden) gave an account of the investigations they had carried out on three different types of equipment – one of Swedish, one of Swiss and one of French manufacture. These tests were made at Harsprånget and included the interruption of a transmission line 500 km. long at 600 kV and of an unloaded 300-MVA transformer at the end of this line when supplied by two 105-MVA alternators. In a further test a 380-kV transformer at Harsprånget was loaded with reactors with ratings between 40 and 180 MVA at 420 kV, the system being supplied through the 380-kV line from Midskrog with the whole network behind it. Adequate protection of the plant against overvoltages was arranged by replacing the normal lightning arresters by rod gaps in series with mat resistances 25 m. long. These gaps were set to a flash-over voltage of 1,000-kV crest value to earth.

The results of these tests showed that the highest overvoltage factor obtained was 2·4 with an oil-minimum circuit-breaker connected to a reactor-loaded transformer. Under the same conditions the factor with the air-blast circuit breakers was 2·1. In the case of an unloaded transmission line, the factor with an oil-minimum circuit-breaker was also 2·4, but only 1·3 with an air-blast circuit-breaker, while with a line connected to an unloaded transformer it was 2·3 and 1·5 respectively. In the case where an unloaded transformer was used the factor with an oil-minimum circuit-breaker was 1·5 and with an air-blast circuit-breaker 1·7. The authors concluded that the switching overvoltages on a 380-kV network would be less than on those operating at lower values.

SWITCHING OVERVOLTAGES

In a paper on the "Limiting of Switching Overvoltages," Mr. L. R. Bergström, Mr. O. Johansen and Mr. B. Grundmark (Sweden) concluded, as a result of both field and laboratory tests with the same three types of circuit-breakers, that lightning arresters easily dealt with the surges when inductive currents were interrupted. On the other hand, when capacitive currents had to be broken non-linear resistances were preferable. When employing bulk oil circuit-breakers, the spark gaps should not be connected to the terminals to obviate the risks of re-striking when the moving parts had completed the major part of their travel.

In a long paper on "Switching Overvoltages – Means for Their Reduction and Regulations for Circuit-Breakers," Mr. S. Teszner, Mr. E. Maury and Mr. M. Perloni (France) gave a summary of the theoretical aspects of the interruption of inductive and capacitive circuits as well as a number of results of experimental investigations. Their conclusion was that the switching overvoltages of small inductive and capacitive currents only caused damage to the equipment when there was a combination of unfavourable circumstances. Such a combination was comparatively rare, although it must be taken into account in view of the frequency with which circuit-breakers were operated. The risks attendant on such switching operations could be diminished by the use of two-stage interruption between which appropriately dimensioned resistances were temporarily inserted in the circuit or by using external protective devices, such as lightning arresters or damping resistances.

In the present state of our knowledge it could not be guaranteed that circuit-breakers without these special features would never produce high overvoltages. The risk of such overvoltages also depended on the insulation level of the system and the steps that were taken to protect it from lightning. These being the conditions it did not seem that it was an appropriate time to lay down a limit for switching overvoltages. It would, however, be useful if designers would specify the maximum overvoltage amplitudes which could be produced by a given circuit-breaker under certain operating conditions, as this was a necessary preliminary to the formulation of regulations.

Such regulations, it must be stressed, would complicate test conditions and necessitate the provision of special equipment so that their economic consequences would be considerable. Before adopting them, therefore, it would appear more reasonable to study the actual test equipment that would be required.

CIRCUIT-BREAKER TESTING PLANT

The problem of how the capacity of circuit-breaker testing plant was to be increased so that the latest equipment could be investigated was dealt with in several papers. Generally speaking, it was pointed out that either new units could be added to existing equipment or "synthetic" methods could be adopted, in which the arc was fed from two independent sources, one of which supplied the current and the other the recovery voltage.

An example of the first method was given by Mr. J. Christie and Mr. H. Leyburn (Great Britain) in a paper entitled "A New Research Station for High-Power Circuit-Breakers." This gave an account of the considerations which had led to the building of the new Reyrolle Research Station at Hebburn. The equipment of this station has already been described in ENGINEERING on page 442, *ante*, so that it need only be stated here that it was constructed after the alternative of both field and synthetic testing had been investigated.

The authors pointed out that while field testing was primarily useful for the final proving of circuit-breakers under the specified conditions of circuit severity met with at the point in the power system where the tests were being carried out and also for certain supplementary tests, such as the switching of lightly-loaded lines, it did not provide the range and flexibility necessary for research and development work. Synthetic testing, as developed at present, was useful for some research work, but the results obtained could not be accepted as a reliable indication of the performance of large circuit-breakers. Thus neither was a satisfactory alternative to a short-circuit testing station with high output at which tests could be carried out under the widely varying conditions likely to be met with in service.

THE WEIL CIRCUIT

Arguments for indirect testing were dealt with in a paper on "The Weil Circuit for Testing High Voltage Circuit-Breakers with Very High Rupturing Capacities," which was presented by Mr. J. Biermanns (Germany). These indirect methods could be divided into two groups. The first necessitated splitting the circuit-breaker into a number of separate units, each of which could be fully tested with the power available. This imposed limitations on the design; besides which, in spite of precautions to equalise the voltage, it was uncertain whether the voltage distribution in the final circuit-breaker actually corresponded with that obtained by this sub-division, since conditions might be disturbed by secondary effects, such as post-arc conductance. Whether this was so could only be ascertained by testing the complete circuit-breaker at full power.

In the second method of indirect (or synthetic) testing, separate current and voltage circuits were used, the principle being that the current and voltage stresses did not occur simultaneously. The current was supplied from a test generator at relatively low voltage and the voltage from a direct-current circuit. The objections to circuits of this kind were that the current was distorted owing to the comparatively high arcing voltage; that the voltage was distorted by the post-arc current; and that there was delay between the application of the test current and voltage.

These disadvantages were overcome in the Weil circuit by connecting a high-voltage oscillating circuit to the circuit-breaker under test during the arcing period. The short-circuit stresses at opening were thus simulated and only slight distortion occurred. The oscillating current fell to zero at the same rate as the short-circuit current and there was no currentless interval between arc extinction and the following test voltage. The recovery voltage could also be varied and all the conditions met with on power systems accurately reproduced. The system was in regular use in the high voltage laboratory of the Allgemeine Elektricitäts Gesellschaft at Kassel for tests on 220-kV open-jet circuit-breakers with ratings up to 6,000 MVA.

RE-STRIKING VOLTAGE CONDITIONS

"The Present and Prospective Re-striking Voltage Conditions on the British 132-kV and 275-kV Networks" were dealt with in a paper by Mr. L. Gosland and Mr. J. S. Vosper. In this the results were given of a survey of the inherent re-striking voltage characteristics, which were representative of all the circuit-breakers on the British 132-kV grid. Limiting conditions for this system had, said the authors, been evaluated for the present state of development and a forecast of its probable development had been made for both 2,500-MVA and 3,500-MVA substations. The limits for 1,500-MVA substations, which were remote from large power stations, had also been determined and an estimate had been made of the limiting conditions for probable 7,500-MVA, 275-kV substations.

The conclusion to be drawn from these investigations was that, in order to specify the re-striking voltage conditions appropriate for circuit-breakers on systems of a given voltage and short-circuit power, it was necessary to foresee clearly the ultimate development of the network. At voltages of 132 kV and upwards it seemed likely that the rates of rise of re-striking voltage, calculated for the most onerous conditions, would occasionally be closely approached in practice, unless it could be assumed that three-phase "with-earth" fault would not occur; or that substantial lengths of insulated conductor would in all cases remain connected beyond the faults. There were a considerable number of substations at which the severity was much less than the maximum.

POST-ARC CURRENTS

In a paper on "Post-Arc Currents in High-Voltage Circuit-Breakers" Mr. S. Teszner (France) and Mr. J. Blase (Belgium) presented a series of new observations on post-arc currents which were the result of work at the Station d'Essais a Grande Puissance. These currents were regarded as of great importance in the design of future circuit-breakers. In those types in which the capacity of the means of deionisation was practically independent of the rupturing current the characteristics of the post-arc current provided a criterion of that capacity. Where, however, the capacity of the means of deionisation was a function of the rupturing current the characteristics of the post-arc current were more uncertain in their effect, although they might supply useful information on the capability of the circuit-breaker to pass through the critical zone of rupture and upon the ceiling of rupturing capacity, in so far as that was not determined by the mechanical or thermal stresses in the explosion pots. The duration of the post-arc current was also valuable in comparing the variations in the same type of apparatus for any value of the current to be ruptured.

In turn, the post-arc current characteristics provided useful information about the sensitivity of circuit-breakers to circuit characteristics, in particular, as far as the inherent frequency of the latter was concerned. Moreover, the post-arc current allowed the damping of the inherent transit phenomena in the circuit-breakers which could be expected when rupturing small inductive or capacitive currents, to be determined, as well as the possibilities of applying certain methods of indirect testing.

To be continued

THE LONG-LIFE INTERNAL-COMBUSTION TURBINE*

By T. W. F. Brown, D.SC., S.M.†

Herbert Akroyd Stuart was one of the major figures in the development of the oil engine. Professor William Robinson, who was Professor of Engineering and Technology at Nottingham University from 1890-1924, was closely associated with his work, and it is therefore appropriate that these memorial lectures come under the auspices of this University. He commenced his work on the oil engine in 1886 and by 1890 had two compression-ignition heavy oil engines built and working, in both of which was first applied the principle of direct injection, now accepted as fundamental in modern oil-engine construction. As will be shown, most of the developments in gas turbines using oil as fuel centre on direct combustion of the oil within the gas turbine. Unlike the reciprocating oil engine, however, the different phases of the cycle take place in successive units – compressor, combustion chamber and turbine.

At the time Akroyd Stuart was starting his work no practical high-speed rotary machinery had been evolved. The first step in this direction came in the 1890's with the development of the steam turbine by Sir Charles Parsons, and rotary compressors of both the axial-flow and centrifugal types were evolved during the following decade. The efficiency of these early rotary machines, however, was not high enough to meet the requirements of gas-turbine work. At the relatively low gas temperatures then possible the power developed by the turbine was almost wholly absorbed in driving its own compressor, so that the net output obtained was negligible. For further progress it was necessary that considerably more work should be produced in the turbine when the hot gas expanded through it than that required for the compression of the air entering the combustion chamber. For present-day component efficiencies in the simple cycle, this requires that the temperature of the gas should be above a value in the range 600 to 800 deg. F., depending on the pressure ratio chosen for the cycle. It required the combined efforts of metallurgists and aerodynamicists working for many years before engineers could utilise higher temperatures and so improve the efficiencies of rotary machinery that gas turbines could be evolved.

TYPES OF GAS TURBINES

From this work three main types of rotary prime movers have been developed: (1) the external-combustion open-cycle gas turbine; (2) gas-turbine machinery with external heating of the air, commonly known as closed-cycle gas turbines; and (3) the internally-heated or open-cycle gas turbine. At present most of the development work on gas turbines throughout the world is of the third type. This third type further subdivides into units in which the heat is liberated at constant volume or at constant pressure. Early gas turbines were of the constant-volume type, i.e., explosive combustion in timed cycles. Present developments are generally concentrated on units in which the heat is liberated at constant pressure.

The number of possible gas-turbine cycles is very large. It is one of the features of this type of machinery that it can be adapted to many different applications and can be as simple or complicated as the economics of the case permit. In this lecture only a few of the more common arrangements can be referred to, together with some details of the types of components suitable for long-life operation. The performance at full load is mainly considered, although some reference is made to part-load performance in a comparison made later in the lecture.

The two main criteria at full-load operation are thermal efficiency and the amount of air used in relation to output. The simplest form of gas turbine consists of a compressor, combustion chamber and turbine, and Fig. 1 shows the components in diagrammatic form of the Derwent V jet-propulsion engine. The centrifugal compressor is indicated by 1. Between 2 and 3, air discharged by the compressor is heated by oil burnt in the combustion chamber which passes through the guide vanes and drives the turbine which is coupled to the compressor. In this case the turbine develops only sufficient power to drive the compressor and the gas then develops speed by further expansion to atmospheric pressure, which results in thrust at the outlet or jet pipe. This is the simplest form of gas turbine, in which all the useful work appears as thrust for propulsion of an aeroplane. The whole gas turbine can be thought of as a self-contained unit providing hot gas at pressure and high speed to the jet. Fig. 2 shows the temperatures associated with the cycle. The line between points 1 and 2 represents compression, between 2 and 3 represents heating at practically constant pressure (except for some pressure loss in the combustion chamber), between 3 and 4 the line represents the fall in temperature by expansion of the gas through the turbine, and between 4 and 5 the further expansion of the gas which takes place before passing through the jet pipe.

Fig. 3 represents the extension of the hot-gas turbine unit to provide power, in this case at the propeller of an aeroplane. As before, the line between points 1 and 3 (Fig. 4) represents compression, between 3 and 4 the heating of the air in the combustion chamber, between 4 and 5 the expansion of the gas in the turbine driving the compressor, and between 5 and 6 the further expansion of the gas through the turbine driving the propeller.

The maximum temperatures shown in Figs. 2 and 4 are about 1,550 deg. F. To reduce weight and space as much as possible only single- or double-row wheels running at high blade speeds are employed. The resulting combined stress in the blading is of the order of 17 tons per square inch, which gives a life of about 500 hours. Such turbines can only be used at these temperatures by accepting a short life.

FACTORS AFFECTING LIFE

In gas-turbine machinery life is a very important factor. For short-life machinery, rupture strength at the operating temperature is all-

TABLE I—RELATION BETWEEN GAS-TURBINE LIFE AND THE STRESS FOR A GIVEN CREEP

Life in Hours	250	500	2,000	20,000	100,000
Blade Stress for 0·1 per cent. extension at 1,200 deg. F. (Material, Nimonic 80). Tons per sq. in.	19·3	17·8	15	10·6	7·8
Corresponding Blade Speed ft. per sec. Assuming $\frac{Dm^*}{h} = 8$	1,250	1,200	1,100	925	800
Number of Stages for Constant Heat Drop	1	1	1	2	3
Rotor Stress for 0·1 per cent. extension at 1,200 deg. F. (Material, G.18B). Tons per sq. in.	8·3	7·3	6·0	3·8	2·0
Blade Speed to give above stress neglecting redistribution of stress due to creep, ft. per sec. Assuming $\frac{Dm^*}{h} = 8$	530	500	450	360	260
Number of stages for constant heat drop	5	6	8	12	23

* Dm = mean blade diameter; h = blade height.

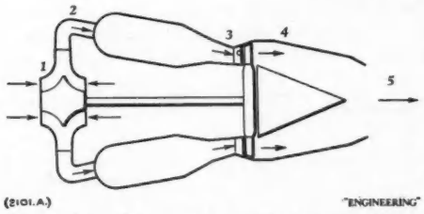


Fig. 1 Rolls-Royce Derwent V jet-propulsion engine.

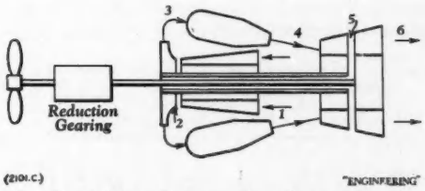


Fig. 3 Bristol Proteus aircraft-propeller gas turbine.

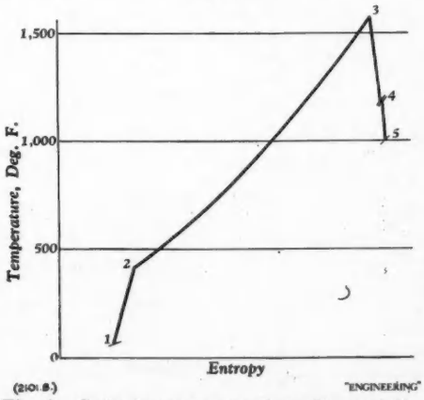


Fig. 2 Cycle temperatures of the Derwent V.

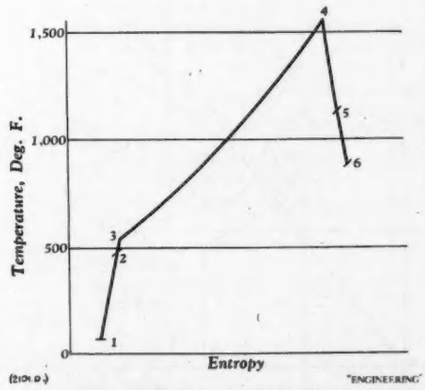


Fig. 4 Cycle temperatures of the Proteus.

* *Akroyd Stuart Memorial Lecture delivered at the University of Nottingham on Friday, March 5, 1954. Abridged.*

† Director of Research, Pametrada Research Station, Wallsend-on-Tyne.

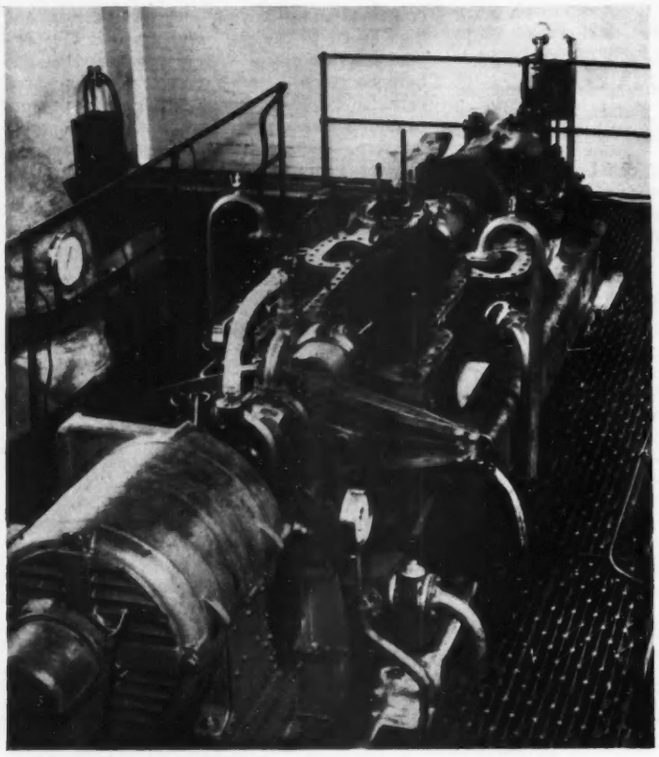


Fig. 5 The first long-life gas turbine to operate in Britain : the 500-s.h.p. test unit built by C. A. Parsons & Co., Ltd., in 1944.

important. For long life the controlling factor is the creep of the metals at any given stress and temperature level. Table I, on page 717, shows this on simplified assumptions.

Creep may be defined as the continuous deformation that occurs when a metal at elevated temperature is subjected to a constant tensile stress. The rate of deformation depends on the metal, time and temperature. The behaviour of a metal at elevated temperature bears no relationship to its room-temperature mechanical properties and cannot be determined from short-time high-temperature tensile tests. One of the most significant factors in the behaviour of metals at elevated temperatures is the effect of time. For a specific temperature, the stress that can be applied to a metal without deformation exceeding a certain value, rapidly falls with time, and the use of newly-developed alloys for long-life applications involves excessive extrapolation of short-time data. Such extrapolation is liable to be very misleading and should not be undertaken lightly.

Few high-temperature materials have been tested to more than 20,000 hours, far less to 100,000 hours. The materials used in such tests would be obsolete before the tests had been completed. The figures in the final column (100,000 hours) have been extrapolated.

In considering life, 250 to 500 hours is only suitable for special applications such as propulsion in an aeroplane, 2,000 hours at full power equals 83·5 days and would be suitable for naval machinery in which full power is used only on rare occasions even under war conditions. On the other hand, merchant ships, operating at full power for 200 days a year, have to have a life of over 100,000 hours built into the machinery to give a useful life of more than twenty years.

Where a gas turbine is built for a short life, the rotor, which has few stages, can be cooled by air and the stress in the blading determines the design. Where long life is required, however, the stress in the rotor is the limiting condition. Although the assumption that rotor stress is no redistributed is an over-simplification, Table I nevertheless shows how much the whole character of the design is affected by the life requirement. For long-life units the temperature is limited to about 1,250 deg. F. by the foregoing considerations. Where residual fuel is to be burned, this temperature limitation is also occasioned by the corrosive effect of constituents of the fuel ash referred to later. It will also be found that the pressure ratio chosen for the cycle is important.

500-S.H.P. LONG-LIFE GAS TURBINE

C. A. Parsons and Company, Limited, began to operate a long-life 500-shaft horse-power gas-turbine test unit late in 1944. This was the first long-life unit to operate in Britain. The temperature in relation to the materials then available was limited to 1,100 deg. F. Fig. 5 shows this unit, consisting of compressor, heat-exchanger, combustion chamber and turbine, which not only drives the compressor but also develops additional power for external use. The compressor is of the axial-flow type and can be seen in the middle of Fig. 5 with the driving turbine at the remote end. The external power developed by the turbine is absorbed by the water brake shown in the foreground.

Fig. 6 shows the variants of this simple cycle in performance with pressure ratio and turbine inlet temperature. It will be seen that the pressure ratios are very much lower than those applying to the expansion of steam through a turbine.

Pressure losses are therefore very important, particularly in the combustion chamber, ducting and heat exchanger. The summation of the percentage pressure losses, each expressed in relation to the total pressure at which the loss occurs, should not exceed 4 to 6 per cent. in a simple turbine cycle, increasing to a maximum value of 10 to 12 per cent. in a complex cycle. As so much negative work is to be performed by the compressor in a simple cycle, the gas turbine performance is greatly affected by the turbine and compressor efficiencies; an improve-

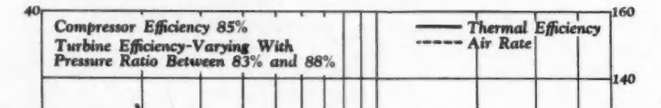


Fig. 6 Performance of basic gas-turbine cycle with no heat exchanger.

Fig. 7 (below) Characteristics of typical axial-flow compressor. Stable operation is only possible in the area below and to the right of the surge line.

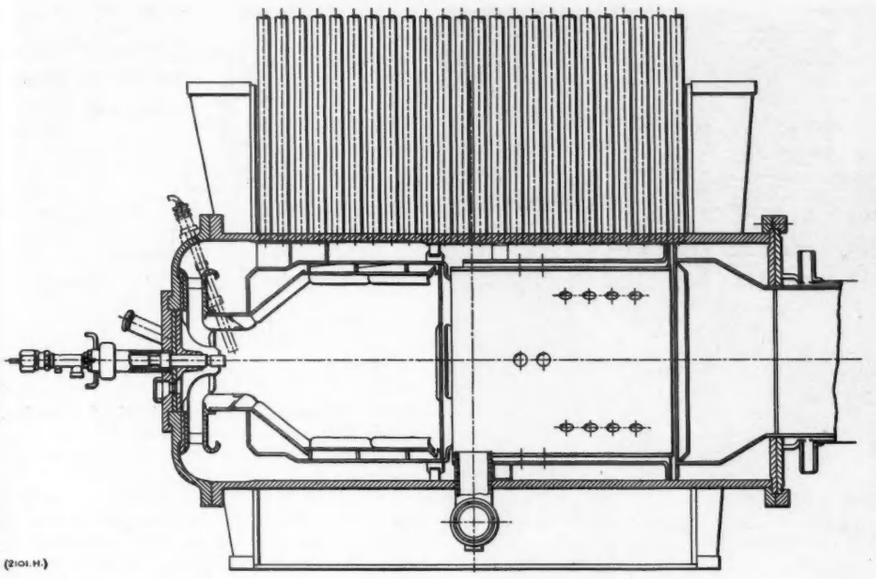


Fig. 8 Combustion chamber for the B.T.H. gas turbine installed in the tanker Auris.

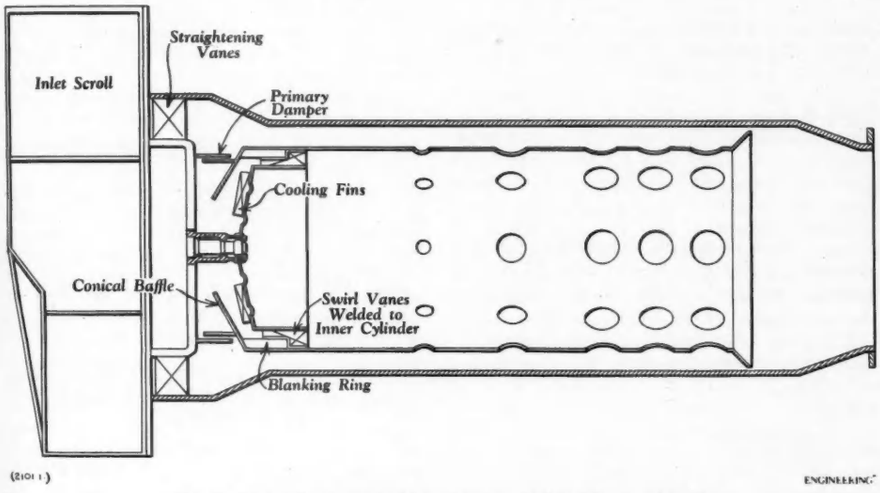


Fig. 9 Metal-lined combustion chamber designed by Pametrada.

ment of one per cent. in the compressor efficiency gives a three per cent. greater output in an average cycle at a temperature of 1,250 deg. F. It has been shown already that gas turbines for long life operation are necessarily of the multi-stage type. The multi-stage design also reduces the leaving loss from the last stage. The blades are usually twisted to give high efficiency to take account of variation of blade speed along the blade length and are also designed on free-vortex flow principles.

Compressor Design. – Unless volumetric flow is very small, the compressor used is of the axial-flow type as this type has a higher efficiency than the centrifugal compressor (the efficiency of the axial-flow compressor is 85 to 88 per cent. as compared with 80 to 82 per cent. for the centrifugal compressor). The characteristics of an axial-flow compressor are very important. Fig. 7 shows the characteristics of a typical axial-flow compressor. Stable operation is only possible in the area below and to the right of the surge line. The shape of the "operating line" is controlled by the arrangement of the cycle and it is essential for the operating line to lie below the surge line in the normal operating range. With some cycles surging may occur at low speeds and it is then necessary to bleed a small quantity of air from the compressor to maintain stable operation.

Combustion Chambers. – The combustion chamber design varies according to the fuel to be used and although pulverised coal and peat have been successfully burned in gas turbines, the best fuel is natural gas and the fuel most commonly used is distilled oil. Great efforts have been made, however, to enable residual fuels to be burned. In the majority of long-life installations only one or two combustion chambers are employed in contrast with the multiplicity of small combustion chambers used in aeroplane units. Among the reasons are, firstly, that the cycle efficiency depends on the average inlet temperature to a turbine while the life is dependent on the maximum temperature applying to a part. It is therefore extremely important that large variations in the gas-outlet temperature should not occur. It is easier to arrange for this in one or two combustion chambers than in a multiplicity of combustion chambers in which variations in oil flow to sprayers, varying air flow to the combustion chambers and similar factors may make matching of the outlet temperatures very difficult. Secondly, volume and weight are not, in general, vital criteria in the design and the resulting simplicity in control systems, sprayer design, etc., is worth more than saving in space and weight.

Two typical long-life combustion chambers are shown in Figs. 8 and 9. Fig. 8 shows a combustion chamber for the tanker Auris installation designed by the British Thomson-Houston Company and Fig. 9 a metal-lined combustion chamber designed by Pametrada. They are of the straight-through type, Fig. 8 having a ceramic lining in the flame zone and Fig. 9 a metal wall cooled by the excess air not required for combustion. The flame requires about 30 per cent. excess air to burn the oil droplets completely and the total excess air required to produce an outlet temperature of 1,200 deg. F. is about 200 per cent.

Heat Exchangers. – The addition of a heat exchanger transfers heat from the exhaust gas to the combustion air and hence reduces the amount of heat to be supplied by combustion of fuel in the combustion chamber, thus having a marked effect on efficiency as shown in Fig. 10. The effect on the air rate is seen to be small. The important property of a heat exchanger from the point of view of efficiency is the thermal

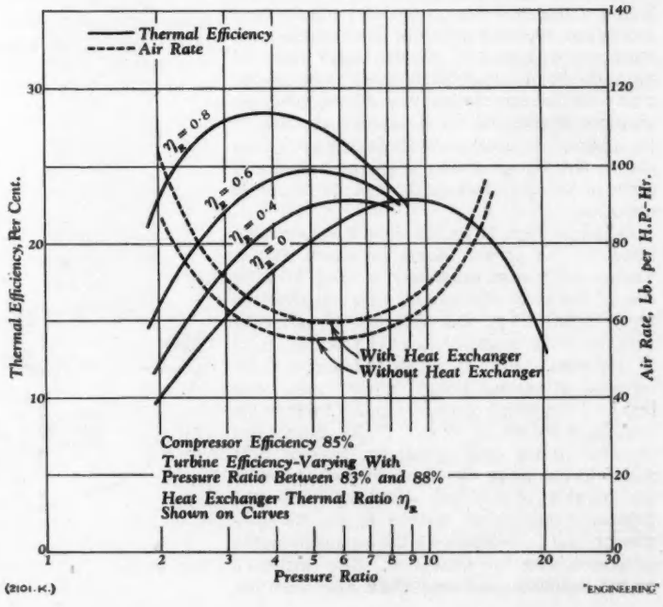


Fig. 10 Effect on thermal efficiency of adding a heat exchanger. Maximum temperature 1,250 deg. F.

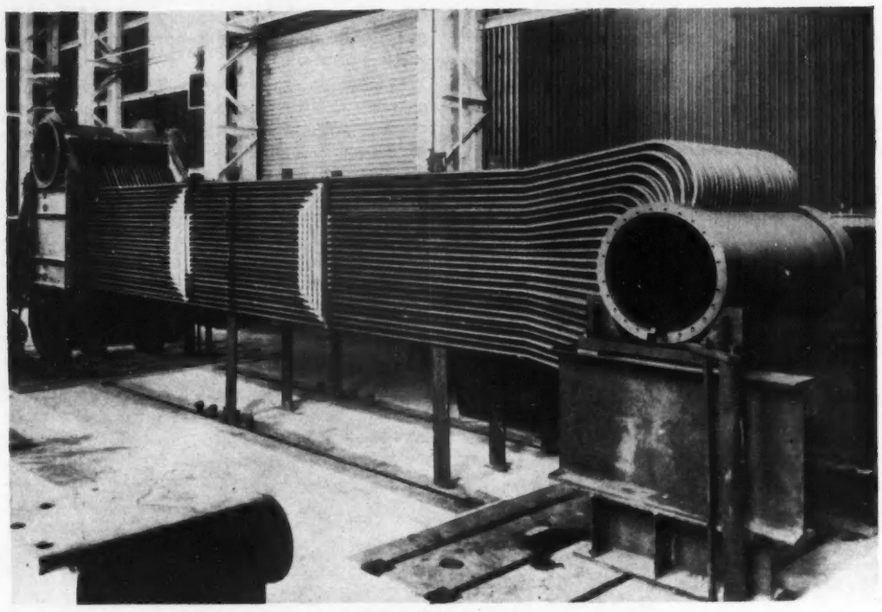


Fig. 11 Heat exchanger for the tanker Auris.

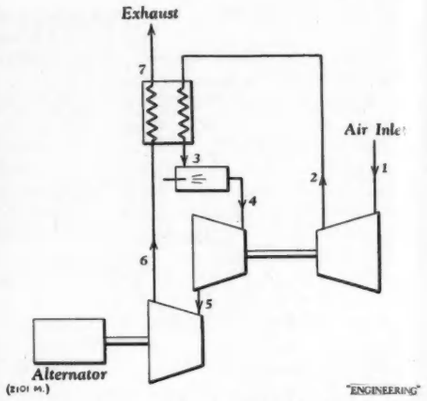


Fig. 12 Diagram of Auris gas-turbine installation.

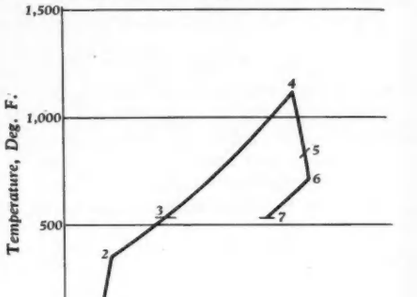


Fig. 13 Cycle temperatures of Auris gas turbine.

ratio. This is the ratio of the actual temperature rise of the air to the temperature rise which would occur if the air were heated up to the turbine exhaust temperature. At present, most heat exchangers are of the tubular type. It can be shown that the weight and volume of the tube nest increase rapidly with thermal ratio. Considerations of weight and space prevent thermal ratios higher than 0·8 being used for open-cycle gas turbines and much lower thermal ratios may have to be accepted where weight and space are restricted. A typical heat exchanger is shown in Fig. 11; this is also for the Auris installation.

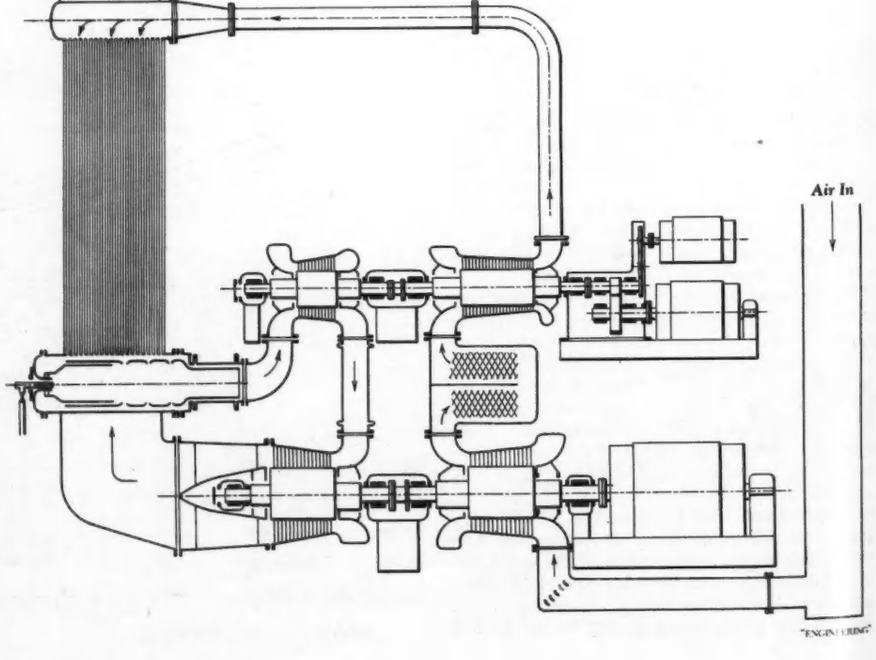
A reduction in heat-exchanger weight can be obtained at a given thermal ratio by providing secondary surfaces on both the air and gas sides. It is also possible to use two separate heat exchangers, in one of which the hot exhaust gas transfers heat to a liquid metal, while in the other the liquid metal gives up this heat to the combustion air. If externally-finned tubes are used in these liquid-metal coupled heat exchangers the result is a large reduction in total weight and bulk as compared with an ordinary tubular heat exchanger. A third type of heat exchanger is the regenerative type, in which higher thermal ratios can be obtained than in those of the tubular type. In the regenerative type of heat exchanger matrices of material are exposed alternately to the gas and air streams, transferring heat from one to the other. Since the gas and air are at different pressures, leakage through seals becomes important.

Diagrams Figs. 12 and 13 show the gas turbine fitted to the tanker Auris in which British Thomson-Houston machinery is used to drive one of the turbo-alternators. The set develops about 1,200 s.h.p. and the thermal efficiency with an inlet temperature of 1,110 deg. F. is 21 per cent. Fig. 13 shows the temperatures involved at various points in the cycle. The line 1 – 2 represents compression, 2 – 3 represents heating of the air on its way to the combustion chamber in the heat exchanger, 3 – 4 is heat added to the air in the combustion chamber by the burning of fuel oil, 4 – 5 represents the expansion through the turbine driving the compressor, and 5 – 6 represents the expansion in the turbine driving the alternator. The line 6 – 7 on the temperature-entropy chart represents the cooling of the exhaust gas by giving up its heat to the air in the heat exchanger before its discharge at 7 to the funnel.

This machinery has now operated at sea for more than two years and the results have been very successful. The maximum temperature used is about 1,160 deg. F., the compression ratio is 4·2, the maximum pressure at discharge from the compressor being 47 lb. per sq. in. The machinery in the Auris can be regarded as a gas turbine driving an alternator of 930 kW capacity. A similar turbo-generator of 1,000 kW capacity was produced by W. H. Allen, Sons and Company, Limited, for the British Admiralty*. This has been made in a very compact form for use in warships. Ruston & Hornsby, Ltd., have made a number of very successful

* See ENGINEERING, vol. 172, page 609 (1951).

Fig. 14 Design for proposed B.T.H. marine gas-turbine set, with intercooler, heat exchanger and waste-heat boiler.



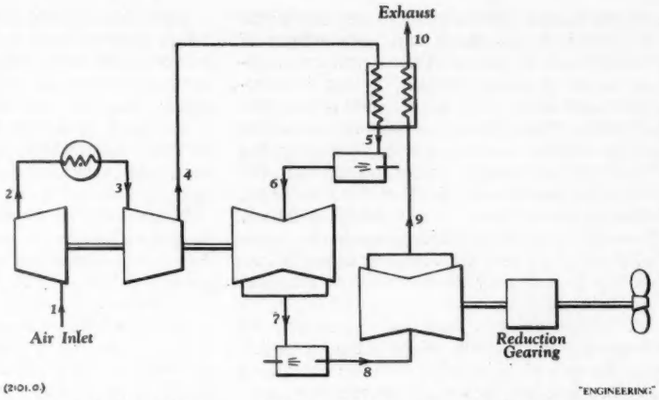


Fig. 15 Pametrada 3,500-s.h.p. marine gas turbine with intercooling and reheat.

gas turbines driving generators of 750 kW to 1,000 kW capacity, depending on whether heat exchangers are fitted or not.

COMPLEX CYCLES

Intercooling. – More complex cycles can now be considered. Dividing the compression into two or more stages enables intercooling to be used, as this reduces the work of compression and so increases the useful output per pound of air pumped through the gas turbine. On the other hand, the compressor outlet temperature is lowered and therefore more heat must be supplied in the combustion chamber although a heat exchanger will restore part of the difference. The net effects are to improve the cycle efficiency and to raise the optimum pressure ratio.

Fig. 14 shows a proposed British Thomson-Houston marine gas-turbine set with two stages of compression with intercooling. The high-pressure turbine driving the high-pressure compressor is coupled to an auxiliary generator and starting motor. The low-pressure turbine drives the low-pressure compressor and provides most of the output power. It will be seen that the exhaust gas, after passing through the heat exchanger, gives up further heat to a steam generator before passing to the funnel. The unit is designed to develop about 4,500 shaft horse-power at an initial gas temperature of 1,200 deg. F. and ambient sea and air temperatures of 77 deg. F. A thermal efficiency of 27½ per cent. is expected at the best point. This figure is based on a thermal ratio of 65 per cent. for the heat exchanger and 85 per cent. for the intercooler. The corresponding fuel consumption is about 0·51 lb. per brake horse-power per hour, although the corresponding figure for shaft horse-power per hour will be about 0·56 lb. to allow for the losses between alternator and motor.

Reheat. – If the expansion in the turbines is carried out in two stages and the gas is re-heated between the stages, there is an increase in the work produced by the turbines and hence the useful work per pound of air is increased. Additional heat has to be supplied in the reheater combustion chamber, but, on the other hand, more heat is recovered in the heat exchanger due to the higher turbine exhaust temperature resulting from reheating.

This leads to the Pametrada 3,500 shaft horse-power gas turbine in which both intercooling and reheat are employed. This turbine, which was described in ENGINEERING, vol. 176, page 491 (1953), has been operating since the end of 1948, and has been used latterly for extended running with residual fuel. The cycle is shown in Fig. 15, where it will be seen that the low-pressure and high-pressure compressors are driven by a common shaft from the high-pressure turbine with intercooling between the two compressors. The high-pressure discharge is led through the heat exchanger to the primary combustion chamber. The gas then passes through the high-pressure turbine and is re-heated before entering the low-pressure or power turbine. The exhaust from this turbine goes through the heat exchanger before passing to the funnel. The various temperatures in the cycle are shown on the heat-entropy diagram, Fig. 16. Points 1 to 2 show the first compression points, 2 to 3 the cooling at constant pressure in the intercooler, points 3 to 4 the compression in the high-pressure compressor, 4 to 5 the heat added to the compressed air in the heat exchanger and 5 to 6 the heat added to the gas by combustion of fuel. Points 6 to 7 represent the expansion line in the high-pressure turbine, points 7 to 8 the reheat between the high-pressure turbine exhaust and the low-pressure turbine inlet, 8 to 9 the expansion in the low-pressure turbine, followed by 9 to 10 the heat given up by the exhaust gas passing through the heat exchanger on its way to the funnel.

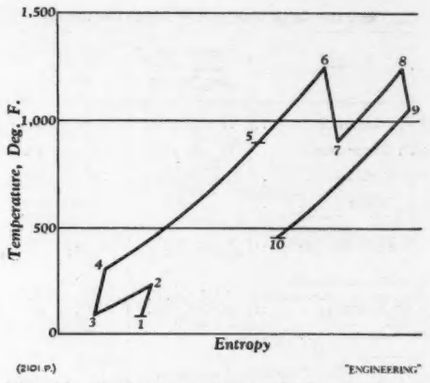


Fig. 16 Cycle temperatures of Pametrada gas turbine.

A still more complex cycle is shown in Fig. 17 which represents the design produced by Rolls-Royce for the British Admiralty. This is a medium-life gas turbine, developing 5,400 shaft horse-power and is intended for installation in a gunboat. In this case three stages of compression are employed with two of intercooling. Some heat exchange occurs at full load and three turbines are employed in series, the output turbine representing the expansion line between points 9 and 10 on the temperature-entropy curve, Fig. 18. A detailed description of this installation will be found in ENGINEERING, vol. 176, page 673 (1953).

COMPARISON OF ROLLS-ROYCE AND PAMETRADA MARINE GAS-TURBINE DESIGNS

It may be of interest to contrast these two gas-turbine units having rather more complex cycles. The Rolls-Royce RM.60 is a brilliant design in relation to weight and space occupied. The turbines are of medium life (1,000 hours at full power) and the set weighs 5 lb. per horse-power. On the other hand, the Pametrada 3,500 h.p. gas turbine weighs a total of about 150 tons, i.e., about 95 lb. per horse-power, but it has a designed life of 100,000 hours and operates at an inlet temperature of 1,250 deg. F. Table II on page 772 summarises the design particulars.

In order to achieve the small size and space, the Rolls-Royce design uses very much higher gas speeds. The comparable losses are summarised in Table III, from which it will be seen that the Pametrada set gains greatly by having a larger duct size with, of course, the disadvantage of much greater volume.

Both gas turbines take some air bled from the compressors. In the Pametrada gas turbine it is required for glands and balancing of thrusts.

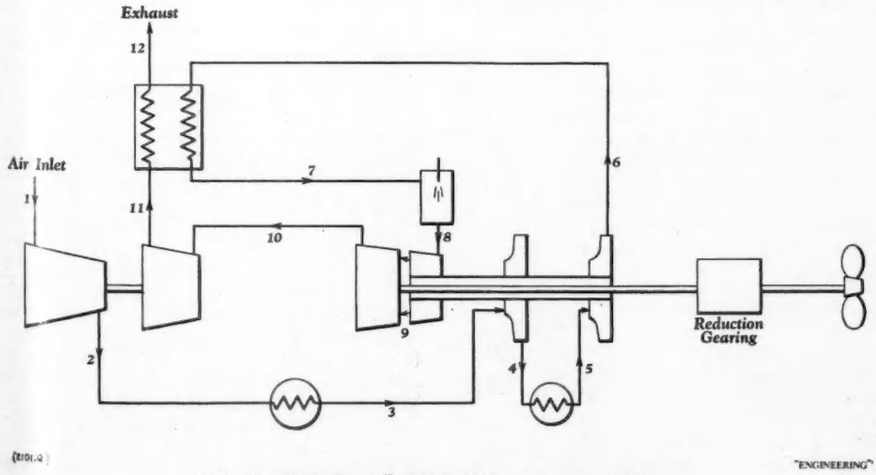


Fig. 17 Rolls-Royce medium-life marine gas turbine.

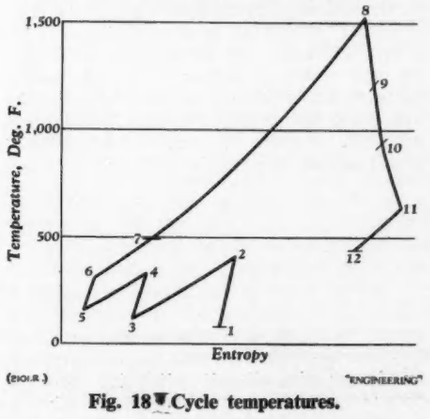


Fig. 18 Cycle temperatures.

TABLE II.—*Design Particulars of Marine Gas Turbines*

—	Pametrada 3,500 s.h.p. Gas Turbine	Rolls-Royce R.M.60. 5,400 s.h.p.
L.P. Compressor	11 stage axial, 2·06 : 1	11 stage axial, 4·35 : 1
H.P. Compressor	17 stage axial, 2·63 : 1	2 stage cent'l., 4·5 : 1
H.P. Turbine	13 stage double flow	1 stage single flow
I.P. Turbine	—	2 stage single flow (power turbine)
L.P. Turbine	8 stage double flow (power turbine)	2 stage single flow
Overall pressure ratio	5·2	18·0
Max. cycle temperature	1,250 deg. F.	1,520 deg. F.*
Overall mass flow	48 lb per sec.	65 lb. per sec.
S.H.P.	3,500	5,400
Shaft r.p.m.	85	675

* Reheat not employed.

TABLE III.—*Pressure Losses and Ducting Velocities at Full Load*

—	Pametrada 3,500 s.h.p. Gas Turbine		Rolls-Royce R.M.60	
	$\frac{\delta P}{P}$ per cent.	Vel. ft./sec.	$\frac{\delta P}{P}$ per cent.	Vel. ft./sec.
Intake Ducting	0·6	111	—	—
L.P. Intercooler	2·4	—	2	—
L.P. Intercooler Ducting		105	2·7	259→99
H.P. Intercooler	—	—	1·5	—
H.P. Intercooler Ducting	—	—	0·4	307→108
Heat Exchanger (air side)	1·1	—	2	—
Combustion Chamber	1·4	—		
H.E. & C.C. Ducting	0·8	104→94	3·8	260→79
Reheat Chamber and Ducting	2·25	90	—	—
H.E. (gas side and exhaust)	1·65	98→44	10·9	125
Total	10·2	—	23·3	—
Actual total loss lb. per sq. in $\Sigma\ \delta P$	4·2	—	23·8	—

In the Rolls-Royce set a certain amount is required for cooling the discs in addition. The L.P. compressor bleed in the Pametrada set has now been reduced to 0·8 per cent. by the use of carbon seals. The total compressor bleed in the R.M.60 engine is 9·5 per cent. Table IV summarises the final results at full load and 30 per cent. load consequential on the factors which have already been considered. At full load the Rolls-Royce set suffers from having to by-pass the heat exchanger, but at 30 per cent. load the Rolls-Royce set is very economical, which is a particular feature in naval requirements. Two columns are given for the overall performance of the 3,500-h.p. set, the first one referring to actual measured performance and the second to the estimated performance with a modified L.P. compressor of higher full-load efficiency. This compressor was too large as built and in cutting down the capacity the efficiency suffered.

In comparing the weights of the two units there are several points which should be borne in mind. Firstly, the weight of 13 tons quoted for the RM.60 unit includes the gearing required to reduce the turbine speed to 675 r.p.m., but if this unit were used as the main propulsion set of a tanker, a further speed reduction to 85 r.p.m. would be required, with a considerable increase in the weights of gearing, shafting and propeller. Further, in a tanker the installation would include also auxiliary boilers, auxiliaries, uptakes, funnel, ladders and gratings, spare gear and piping, cocks, valves, etc. The weight of these items for a 6,000 shaft horse-power installation would be about 600 tons, so that the complete weight of the installation would be 613 tons (neglecting the increase in weight corresponding to the further speed reduction). Taking the Pametrada gas turbine as weighing 150 tons, the weight of a similar set of 6,000 shaft horse-power, including all the above items, would be 830 tons. Thus the RM.60 installation would be some 217 tons lighter than the Pametrada installation, but this is now only 26 per cent. of the total installed weight.

A further point is that the picture may be completely altered if the weight of the fuel which must be carried is included with the machinery weight. In a merchant ship the machinery would operate continuously at full power. Taking the full-power fuel consumptions as 0·66 lb. per shaft horse-power per hour for RM.60 and 0·50 lb. per shaft horse-power per hour for the Pametrada unit (0·48 has already been achieved and 0·44 is nearly within sight) then if fuel for 23 days' running is carried the weights of the two machinery installations plus fuel would be equal. If fuel were carried for a longer voyage than this the Pametrada installation would be the lighter of the two. It should be noted that the Rolls-Royce unit would have used up half of its total life at full power in this 23 days' running, while the effect on the life of the Pametrada unit would have been negligible.

Additionally, the Pametrada installation has run for many hundreds of hours on boiler oil so that the fuel costs for this set would be still further reduced by its being able to use a lower grade of fuel. It is apparent how much better such a unit would be for commercial use. On the other hand, for operation at cruising power the RM.60 is the more efficient of the two units, a high efficiency at cruising power being an important requirement for naval machinery.

It is hoped that this contrast of the two designs will be instructive in showing the very considerable effect which service requirements have on the type of design needed, in relation to both machinery weight and fuel consumption. Though this Pametrada unit is heavy, it is pointed out that a naval design of light weight can be produced. In fact, a design was submitted to the Admiralty in 1946 consisting of a high-efficiency long-life base-load or cruising unit fitted with a boost gas turbine to provide full power having shorter life characteristics.

In the Rolls-Royce set the low-pressure turbine coupled to the low-pressure compressor can be regarded as a supercharging unit raising the pressure level throughout the rest of the plant. If the Pametrada 3,500-h.p. set were also pressure charged the effect of adding such a supercharger of 1·6 pressure ratio would be to increase the power available to 7,500 shaft horse-power. The specific fuel consumption would then be 0·442 lb. per horse-power per hour, corresponding to a thermal efficiency of 32 per cent. This is about the best that can be done at a temperature level of 1,250 deg. F., though many mechanical improvements could be made in a new set. It must be remembered that the existing set was designed in 1946.

TABLE IV.—OVERALL PERFORMANCE

—	Full Load			30 per cent. Full Load		
	Pametrada Gas Turbine	Pametrada Gas Turbine (Mod.)	Rolls-Royce R.M.60	Pametrada Gas Turbine	Pametrada Gas Turbine (Mod.)	Rolls-Royce R.M.60
L.P. Compressor Efficiency (per cent.)	78·3	84·0	81	85·0	85·0	83
S.H.P.	3,240	3,430	5,400	972	1,030	1,620
Thermal Efficiency (per cent.)	26·9	29·4	21·2	17·3	17·9	20·6
Specific Fuel Consumption (lb. per h.p. hr.)	0·53	0·48	0·66	0·83	0·80	0·68

APPLICATIONS OF GAS TURBINES

It is proposed now to say something about the possible applications of the gas turbine. The three main fields in which it seems likely to be widely used are marine propulsion, electrical power generation, and railway traction. Each of these applications has its own particular requirements and will call for a different type of unit.

Marine. – It will be clear that the position of the gas turbine in the marine field is potentially very strong, once its ability to utilise the cheaper grades of fuel oil (i.e. residual oils) has been fully proved. In the normal power range of merchant-ship machinery the gas turbine is more efficient than the steam turbine, and is lighter and smaller. Its position *vis-à-vis* the oil engine is more difficult to summarise briefly; the thermal efficiency of the oil engine is higher, but this advantage is to some extent offset by its much higher lubricating-oil consumption and maintenance costs. Moreover for powers above about 6,000 s.h.p. per shaft the oil engine becomes very heavy and bulky, and is at a serious disadvantage relative to the gas turbine in this respect. The steam plant will burn the heaviest grades of fuel oil, and the marine oil engine has recently been developed to burn heavy fuel (although at the cost of still higher upkeep charges), so that to be fully competitive the marine gas turbine must be able to accept similar fuels.

The difficulties met with in burning residual oils in the gas turbine are associated with the deposition of the fuel ash on the turbine blades. The effects of the ash are two-fold: firstly, the blade passages become restricted and progressively reduce the air flow through the unit until eventually the compressor surges, and secondly, at temperatures above about 1,200 deg. F. the ash causes severe corrosion of the blade material. The problem of ash deposition has been studied intensively during the last few years, and although it has proved to be extremely complex and is still not completely understood, the main outlines are now becoming clear. It is well known that the trouble is due primarily to the presence in the ash of compounds of vanadium and sodium. The harmful constituents cannot be removed from the oil beforehand except at prohibitive cost, and the removal of the ash from the gas stream between the combustion chamber and the turbine also appears to be impracticable.

One method of alleviating the trouble is to reduce the efficiency of combustion slightly, in such a way that the carbon particles formed from the burning droplets of fuel are not completely consumed. The majority of the ash remains enveloped in these carbon particles and passes through the turbine without being deposited. Control of the combustion in this way, however, is not easy in the normal straight-through combustion chamber, particularly over a range of air : fuel ratios, and the method is probably too sensitive to be relied on in service.

Much work has been done on the use of additives in the fuel oil, for preventing both deposition and corrosion, and such promising results have been obtained that this method now seems almost certain to provide the final solution. Compounds of silica have been found to be most effective in preventing all but very slight deposition. Much work remains to be done, particularly at higher gas temperatures (i.e., above 1,200 deg. F.), but it can now be said that a solution along these lines is in sight. With regard to the type of gas-turbine machinery most suitable for marine use, the chief requirements are: reliability, good thermal efficiency at full load, and the ability to be reversed and to manœuvre without difficulty. Extreme com-

compactness and light weight are not of vital importance, and are not worth obtaining at the expense of the other qualities mentioned.

The above considerations apply primarily to merchant-ship machinery; for naval machinery there is a much greater emphasis on small size and weight, and it is more important to provide a good thermal efficiency at cruising power than at full power. Manœuvring is facilitated by the use of an independent power turbine. The method of reversing used with steam turbines – by means of a separate astern turbine – is not practicable with gas turbines, and several alternative solutions have been put forward.

Electrical transmission. – This system is rather heavy, costly and complicated, but is reliable and well proven in service. The efficiency is much lower than for the other types of drive, being only about 92 per cent.

Variable-pitch propeller. – The variable-pitch propeller provides a compact and convenient method of reversing, but the propeller has a rather lower efficiency than a fixed-blade propeller owing to the need for a larger boss, and is also more vulnerable. A further disadvantage is that the turbine is unloaded as the propeller blades pass through the zero-pitch position when reversing, with consequent risk of overspeeding.

Mechanical Clutches. – Mechanical clutches will probably be satisfactory if sufficient surface area can be provided for absorbing the very large amounts of kinetic energy in the propeller and shafting when reversing.

Hydraulic Couplings. – This arrangement is practicable and appears to have no serious disadvantages provided that an ahead coupling loss of about 1·7 per cent. can be accepted, giving an overall transmission efficiency of about 96 per cent.

Epicyclic Gearing. – Epicyclic gearing has not yet been applied to marine-propulsion machinery, but apart from its other advantages it seems to offer the most satisfactory solution to the reversing problem. The direction of rotation is determined by braking either an ahead or an astern annulus, and the brakes must be capable of absorbing the kinetic energy of the propeller and shafting when reversing.

ELECTRICAL GENERATION

The oil-fired gas turbine cannot compete with the large base-load steam-turbine machinery in this country, using coal as fuel, owing to the difference in fuel costs, and its use for electrical generation will be limited to peak-load and standby plant. It may also be used for base-load generation in places where oil fuel is cheaper than coal and/or cooling water is not available, and where natural gas is available as fuel. The case for the use of gas-turbine plant for peak-load service rests on the lower cost (including lower costs of buildings), lower standby losses, and the fact that for operation with a low load factor fuel costs are a much smaller item than capital charges.

A number of large gas-turbine units for electrical power generation have been supplied by Swiss firms, the largest being the 27,000-kW set for Beznau power station.* Some of these units have been supplied to countries where the above special conditions apply, others are hydro-electric standby plant, and are normally operated only in winter when the low ambient temperature leads to a high thermal efficiency. In this country several large units are being installed.

A 15,000-kW set at Trafford Park power station, made by the Metropolitan-Vickers Electrical Company, Limited, is about the largest size of gas turbine made in Britain at present.

* See ENGINEERING, vol. 176, page 611 (1953).

Sets of a similar type are under construction by C. A. Parsons and Company, Limited, for Dunston and N.G.T.E., and by the English Electric Company, although the details of the cycles differ among the various makers. John Brown and Company, Limited, specialise in the Escher Wyss closed-cycle gas turbines and have built the 12,500-kW set at Dundee.

It must not be supposed that the gas turbine is necessarily limited to liquid or gaseous fuels. Experimental work on the burning of coal and peat is in progress by a number of firms. The closed cycle may prove to have advantages for burning solid fuel, since ash separators are not then required. As soon as coal-burning has been proved successful, the gas turbine would then be competitive with the steam turbine for base-load generation. There are probably no great differences in efficiencies at existing temperature levels.

RAILWAY TRACTION

Railway traction at one time appeared to be a most suitable application for the gas turbine, since the gas-turbine locomotive would have a much higher full-load efficiency than the steam locomotive and could be made lighter and more compact. Standby losses would also be much smaller. Units so far built have been of single-shaft design, either with no heat exchanger or with a heat exchanger of low thermal ratio. The part-load efficiency curves have not been very good, and since a locomotive spends a large proportion of its operating life at fairly low powers, the efficiency in service has not been much higher than the low value obtainable from steam locomotives. In addition, the gas turbines use a more expensive fuel, so that fuel costs are in fact higher. It has been suggested that use of a compound cycle to improve the part-load efficiency curve would give substantially better results. Considerable efforts are being made in this country and in the United States to develop coal-burning locomotive gas turbines.

OTHER APPLICATIONS

Various other applications have been found for the gas turbine. Perhaps the most important is its use for natural-gas pumping in the United States. A large number of sets have been built for this purpose, all using natural gas as fuel. In this country gas turbines have been installed by the Metropolitan Water Board for water pumping. The automobile application is also well known, although it is doubtful whether the gas-turbine drive for cars will in fact be widely used unless the economy of these very small sets can be improved. The gas turbine will no doubt find other applications from time to time where conditions favour its use.

FUTURE DEVELOPMENT

Long-life gas-turbine machinery so far produced is either completely uncooled or has a relatively small amount of disc or bearing cooling. Blades and rotors run substantially at gas temperature, which is therefore limited by the creep strength of the available materials. The development of an effective and efficient system of cooling would allow gas temperatures to be raised, with substantial increases in efficiency. The potential gain is quite considerable. Since the material of the blades, rotor and casing would be cooled the life of the unit need not be impaired.

The complexity of cycles required to obtain a thermal efficiency of the order of 30 per cent. with a turbine inlet temperature of 1,250 deg. F. required for long-life operation, has already been shown. The main remaining factor in the search for increased efficiency is the use of higher inlet temperatures to the turbine. From long-

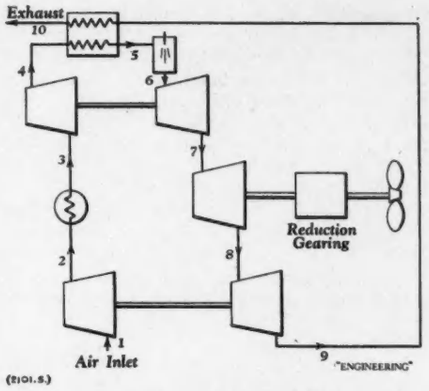


Fig. 19 Proposed cycle for a high-temperature marine gas turbine.

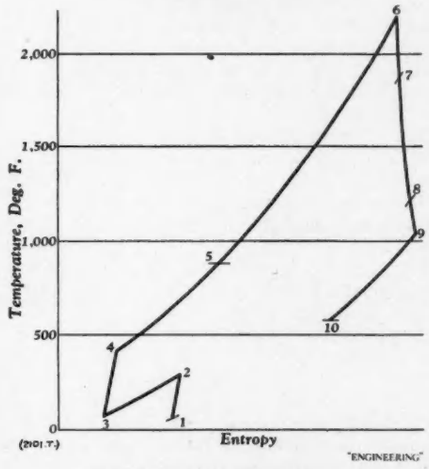


Fig. 20 Cycle temperatures.

life considerations this means that the metal temperatures in all stressed parts must be kept below, say, 1,200 deg. F. while employing very much higher gas temperatures. This can only be done by the use of cooling. It can be interpolated here – How far would the heavy oil engine have developed without water cooling? The three main types of cooling are: – (1) Direct use of cooling air passing along holes and narrow passages within the parts to be cooled; (2) Effusion cooling by passing air through porous sintered compacts forming the walls of the cooled parts; and (3) Water cooling.

Air cooling is the simplest method, as the compressor is already handling large quantities of air, but it can be shown that the bleeding of air from the compressor to provide coolant has two major disadvantages: (1) the air has to be compressed absorbing power, and (2) the outflow of air from blade tips or the edges of nozzles, etc., interferes with the flow of the main gas stream and reduces the aerodynamic efficiency.

Calculations tend to show that effusion cooling will be quite the most efficient method of using cooling air as the air cools the metal surfaces in traversing the pores of the sintered compact, and forms a layer of cool air over the surface which partly insulates the material from the main hot-gas stream. On the other hand, sintered compacts which will pass air through them have not so far been made strong enough to be used at the stresses associated with rotor blading.

Water cooling, particularly if convection cooling in closed circuits is used, has already been proved to be the most powerful means of removing heat from metal surfaces, particularly in rotor blades, where it is associated with a

high centrifugal field, e.g., at a mean blade speed of about 800 ft. per second and a diameter of 16 in. the centrifugal field is equivalent to 30,000 *g*. This high gravitational field causes rapid circulation of the cooling medium in the blades, and hence very effective cooling. In fixed blading and nozzles, where stresses are much lower than in rotor blades, it may be possible to use ceramic material. Tests have already been carried out on ceramic nozzle groups operating at 2,200 deg. F. The tests include a number of thermal shocks induced by shutting off the oil-fuel sprayer, which causes a very rapid fall in gas temperature. The temperature drop in a small interval of time can be as much as 1,200 deg. F.

Figs. 19 and 20 show a cycle similar to the Pametrada 3,500-shaft horse-power gas turbine with the supercharging element added as already mentioned. If this cycle operates at a gas inlet temperature of 2,200 deg. F. and a pressure ratio of about 15 : 1 the thermal efficiency will be about 42 per cent., and the corresponding air rate per horse-power hour will be about 15 lb. It will be seen that the improvement in efficiency over the similar cycle operating at about 1,250 deg. F. inlet temperature is of the order of 33 per cent., and that the air rate is about one third of that for the low-temperature cycle. This means that the compressors and all ducting and similar parts will be one-third in size for the same output, so that not only is efficiency greatly improved, but the resulting sizes and weights in relation to output are also improved by this large factor of 3. For example, at 1,250 deg. F., for an output of 10,500 h.p., the compressor power required is 19,150 shaft horse-power. The corresponding figure for the same output at 2,200 deg. F. is 7,400 shaft horse-power. A great deal of work has to be done before the cooled gas turbine can be produced, but these few figures show how great a gain can be achieved and how very much worth while the goal may be.

★ ★ ★

SELF-CONTAINED DIVING APPARATUS

Compressed-Air Containers

Self-contained diving apparatus designed to permit unrestricted underwater movement at a depth of 10 to 12 ft. for periods up to 1 hr. 10 min. or for short intervals at depths of 100 ft. is being made under licence by Siebe, Gorman and Company, Limited, Davis-road, Tolworth, Surrey. This apparatus, which is known as the Essjee Aqualung, can be worn with a normal swimsuit or special underwater clothing.

Among the suggested uses of the equipment are: inspection of dock walls and yacht hulls; small salvage operations; and clearing fouled propellers.

The diving apparatus consists of one or two containers filled with compressed air which are strapped to the back of the swimmer by means of a webbing harness which includes a weighted belt. A face mask in the form of a visor covers the eyes and nose and Frogman-type flippers are worn on the feet. A valve on the cylinder regulates the flow of air to the lungs and a pressure gauge registers the amount of air in the cylinder in atmospheres. The air is inhaled and exhaled through the mouth by way of a rubber bit held between the teeth. A clip is worn on the nose.

The two larger sizes of this equipment are similar, apart from the fact that one has a single air bottle permitting underwater operation at a depth of 10 to 12 ft. for 35 minutes or 100 ft. for 10 minutes, whereas the other has two bottles which double the operational time. The third size, known as the Junior Tadpole, has one small cylinder allowing 24 minutes at 10 to 12 ft. and 12 minutes at 33 ft. They weigh 25, 50 and 20 lb. respectively.

The M.V. Fairtry is believed to be the first fish-factory ship to be specially built as such. Trawling is done over the stern and the catch is brought up a ramp, after the manner of a whaling factory.

THE FISH-FACTORY TRAWLER "FAIRTRY"

In the course of the discussion of Professor Ir. H. E. Jaeger's paper on "The Design of Large Trawlers," during the recent Spring Meeting of the Insitution of Naval Architects, reference was made to a new fish factory ship, said to be the first in the world to be specially built as such, which was about to go on her trials. The vessel in question, though not named in the discussion, is the M.V. Fairtry, which has been built and engined by Messrs. John Lewis and Sons, Limited, of Aberdeen, for Messrs. Chr. Salvesen and Company, of Leith. By courtesy of the builders, we are able to give below a description of this unusually interesting ship, which combines the functions of a trawler and a fish-processing plant. This in itself is not new, as various ships have been converted to this method of operation, one of them being the Fairfree, belonging to the same owners; but, so far as we are aware, none of them employs the method of trawling over the stern and bringing the catch inboard up a ramp, after the manner of a whaling factory, which is a prominent feature of the Fairtry.

As a trawler, the Fairtry is the largest in the world, having a gross tonnage of 2,605. Her length between perpendiculars is 245 ft., the breadth moulded is 44 ft., and the depth moulded, to the main deck, is 24 ft. and to the bridge deck, 32 ft. She has been built under the survey of Lloyd's Register and to the Society's highest classification for the hull, machinery, and refrigerating machinery, and complies also with the latest requirements of the Ministry of Transport with regard to the crew accommodation, fire-fighting appliances, and the life-saving equipment specified by the International Convention on the Safety of Life at Sea. The main deck is continuous fore and aft and the deck above it, forming a combined bridge and forecastle deck, extends almost for the length of the ship, terminating at the after end at the trawl bridge over the stern ramp, which gives a clear view fore and aft over the working deck. The hull is constructed with a flat plate keel, a clipper stem and a cruiser stern. Resistance tests, self-propulsion tests and tests of manœuvrability were carried out by the Ship Division of the National Physical Laboratory before the detailed design was proceeded with.

The refrigerated spaces comprise two holds and a 'tween deck. The machinery is arranged amidship between the two holds, and the refrigerated 'tween-deck space is forward, above No. 1 hold. There is a continuous double bottom. Oil fuel is carried in the double bottom and in a cross bunker, separated from the engine room forward bulkhead by cold stores and a mess room. The refrigerating machinery is in the engine room, aft of which, and between it and the after hold, is the evaporator room. Aft of this hold is a fishmeal compartment and aft of this again, on the starboard quarter, a liver-boiling compartment.

About half the length of the main deck is taken up with the factory and packing compartments, forward of which, on each side of the engine casing, is part of the accommodation for the crew. The remainder of the accommodation for officers and crew, except that for the captain and the wireless operator, which is on the navigating bridge deck, is on the combined bridge and forecastle deck. In all, there is accommodation for 82 persons. Fresh water is carried in the fore peak tank, in the double bottom and in some of the after tanks, these last containing feed water for the Cochran boiler which forms part of the liver-boiling and fish-meal plant. Others of the after tanks are used for storing liver oil. The batteries of quick freezers are at the forward end of the factory deck.

CONSTRUCTION

The hull is constructed with transverse framing throughout and is mainly riveted except for the shell butts, deck seams and butts, bulkheads and tank top, which are welded. The decks are of steel, but the navigating bridge and the trawl bridge, in range of the compass, are of aluminium alloy. The rudder is of the double-plate type, semi-balanced. The rudder frame and also the stern frame are steel forgings, supplied by Messrs. T. S. Forster and Sons, Sunderland. The exposed decks over the accommodation are wood-sheathed and the underside of the bridge deck, in way of the factory deck, is insulated with Rocksil and faced with sheet metal. The hatch on the factory deck to the 'tween deck is fitted with a Macgregor sliding steel cover. The bridge deck

hatches to No. 2 hold and to the factory deck have flush steel covers, hydraulically operated. On the main deck, No. 2 hold has hinged steel covers.

FISHING AND PROCESSING EQUIPMENT

The gallows frames for handling the trawls are mounted on the quarters, on the main deck, the trawl warps being led round centre and side bollards to the trawl winch, below the boat deck extension. The winch is electrically driven by two motors of 270 brake horse-power each, which can be used together or independently; it can take 1,200 fathoms of 3¼ in. warp on each barrel, and is equipped with the Ward-Leonard system of control. The makers are Messrs. Clarke, Chapman and Company, Limited, Gateshead-on-Tyne, who also supplied the worm-geared warping capstan, two 2-ton cargo winches, and the windlass and bow stoppers. The capstan, winches and windlass are all electrically driven. The trawls are drawn inboard up the ramp at the stern of the vessel and are emptied into the fish pounds on the main deck, at the after end of the factory compartment. Two smaller pounds are provided on the bridge and forecastle deck, one on each side of the ramp.

The processes carried out on the fish comprise gutting, washing, heading, filleting and skinning, wrapping, weighing, quick freezing, packaging and, finally, conveying to the refrigerated holds. The equipment is designed and laid out to reduce handling of the fish to the minimum, but provision is also made for hand filleting and for quick-freezing whole fish or fish steaks. The offal passes to the fishmeal plant below the factory deck, and the livers to the liver-boiling plant aft, where the oil is extracted. Electrically-operated and fully automatic heading, filleting and skinning machines are fitted; these were supplied by the Nordischer Maschinenbau, of Lübeck. The washing machines are by Fisadco, Limited, of Hull, and the weighing machines by Thomas Bishop and Sons, Limited, Glasgow, who also supplied the packing tables and tray racks; the same firm provided the equipment for the galley, which includes an oil-fired range and baker's oven. The cod-liver oil plant was supplied by the shipbuilders, and includes a Mono pump for transferring the oil to the storage tanks.

REFRIGERATION EQUIPMENT

There are two batteries of quick freezers. Fair freezers, made by the J. D. Insulating Company, Limited, L. Sterne and Company, Limited, and the shipbuilders, are installed on the port side; and on the starboard side is a battery of multi-plate frosters supplied by the Bird's Eye Food Company, Limited. Thomas Bishop and Sons have provided the spray glazing machines, and there is a carton binding machine by the Package Sealing Company (Export), Limited. For the supply of flake ice to pre-cool the fish before processing there is a Scale-Ice machine, made by Messrs. Sabroe, of Denmark. Conveyors transfer the fish to the holds, and discharge on to spiral chutes leading to the lower holds. These conveyors, as well as those for the offal, have been supplied by the Moxey Conveyor and Transporter Company, Limited. The Farrar Boiler Works, Limited, were the contractors for the fishmeal plant, which has a capacity of 12 tons of raw fish per day. It consists of four steam-jacketed concentrators discharging into hoppers and so on to a worm conveyor which delivers the product to a Briton grinder. The fishmeal is bagged for stowing.

The insulation of the refrigerated 'tween-deck and holds was carried out by the J. D. Insulating Company, Limited, and consists of Rocksil and Onazote, retained by aluminium sheathing supplied by the British Aluminium Company. The fishroom posts are of galvanised steel and the pound boards and shelves of extruded aluminium alloy, supplied by Messrs. T. I. Aluminium, Limited, and Imperial Chemical Industries, Limited. To enable the hold temperature to be accurately controlled, Malone long-distance thermometers are fitted. The main refrigerating plant, which, together with the evaporators, condensers and pumps, and the brine circulating system, has been supplied by L. Sterne and Company, Limited, Glasgow, consists of three electrically-driven compressors, with cylinders 14 in. in diameter by 9 in. stroke, using Freon 12, and one Mark III Freon compressor.

PROPELLING MACHINERY

The main propulsion machinery consists of a four-cylinder Doxford opposed-piston oil engine of the 48 S.B.4 type, constructed by the shipbuilders; it develops 1,900 brake horse-power at 135 r.p.m. The main-engine auxiliaries, comprising the valve cooling-water pumps, sea-water circulating pumps, jacket and piston water-circulating pumps and forced-lubrication pumps, were supplied by Drysdale and Company, Limited, who were also the contractors for the general service pump, oil-fuel transfer pumps, and the domestic fresh-water and salt-water pumps. The bilge pump is by J. H. Carruthers and Company, Limited. The coolers for the jacket and piston circulating water and for the lubricating oil have been provided by Serck Radiators, Limited, and the centrifugal purifiers for the oil fuel and the lubricating oil by the Alfa-Laval Company, Limited. Messrs. G. and J. Weir, Limited, supplied the main-engine air compressors and the evaporator. For overhauling the main engine there is an overhead electric crane, made by the Anderson-Grice Company, Limited. Maihak indicators are provided for taking power readings on the main engine.

The Cochran boiler, previously mentioned as having been provided for the liver-oil and fishmeal plants, is oil-fired, the oil-burning equipment being of the Wallsend-Howden type. The other auxiliaries for this boiler comprise an Alldays and Onions forced-draught fan, feed pumps by G. and J. Weir, Limited, and a feed-water filter supplied by the Universal Metallic Packing Company, Limited. The electrical generating plant consists of four 245-kW sets, each comprising a Ruston and Hornsby 6VEBZ Diesel engine coupled directly to a direct-current generator constructed by Clarke, Chapman and Company and delivering at 220 volts. The main switchboard, supplied by the Walsall Electrical Company, Limited, extends for the full width of the engine room at the forward end. A shore connection is provided for use when the ship's generators are shut down. There is also a small motor alternator, with a separate switchboard, for supplying the factory-deck machinery; it was provided by Hugh J. Scott and Company (Belfast), Limited. The whole of the electrical installation is in accordance with the requirements of Lloyd's Register of Shipping.

The steering gear, supplied by J. Hastie and Sons, Limited, Greenock, is of the electric-hydraulic two-ram type, driven by twin motors and pumps, and directly coupled to the rudder head. It is controlled by telemotor from the navigating bridge. A hand-operated emergency gear is provided.

The tripod foremast, which is stepped on top of the wheel-house, carries the usual navigation and trawling lights and, on a small platform, the radar scanner. The mainmast is mounted on a light girder connecting the tops of the centre pair of samson posts, at the after end of the bridge and forecastle deck. There is another pair of samson posts immediately in front of the navigating bridge, and a third pair aft, in front of the trawling bridge. Each samson post supports a steel derrick, designed for a safe working load of 2 tons. The masts, samson posts and derricks are all steel tubes, supplied by Messrs. Stewarts and Lloyds, Limited. The four lifeboats, each capable of carrying 50 persons, comprise three wood double-ended pulling boats and one motorboat; all were built by J. Watt and Sons, of Gardenstown, Banff. They are carried in Welin-Maclachlan davits of the gravity type and are hoisted in by electric winches.

Included in the navigating equipment are a gyro-compass, supplied by Messrs. S. G. Brown, Limited; a Kelvin and Hughes magnetic compass; Kelvin and Hughes echo sounders; a Chernikeef log; and a wireless installation with direction-finder, and a Radiolocator Mark IV radar set, all supplied by the Marconi International Marine Communication Company, Limited. Kent " Clear-View " screens are fitted on the navigating and trawling bridges. Most of the instruments are installed on the navigating bridge, with repeaters on the trawling bridge. Messrs. Clifford and Snell, Limited, Sutton, Surrey, have supplied a telephone system between the various working parts of the ship.

For fire-fighting purposes there is an emergency pumping set consisting of a Russell and Newbury vertical single-cylinder Diesel engine of 11½ brake horse-power, driving a Hamworthy self-priming centrifugal pump.

ACCOMMODATION

As previously mentioned, the quarters for the officers and crew are on the main deck and on the bridge and forecastle deck, and the accommodation for the captain and the wireless operator on the navigating-bridge deck. The captain has a day room, a sleeping cabin and a bathroom. The accommodation for the chief engineer is similar to that of the captain, but is on the deck below. The deck officers, engineers, chief steward, and the factory manager and technicians are all accommodated on the bridge and forecastle deck, each having a single-berth cabin. On the same deck, aft of the officers' quarters, are two-berth cabins for the petty officers, and at the forward end are the officers' saloon and smokeroom, with an adjacent pantry. The fishermen, factory hands, greasers and catering staff are on the main deck, some in two-berth and some in four-berth cabins. The galley and the petty officers' messroom are on the main deck and the messrooms for the crew and the stewards on the lower deck.

Particular attention has been devoted to heating and insulating the accommodation, in view of the cold latitudes in which the ship will operate, a complete ventilating and heating installation having been provided by Messrs. Thermotank, Limited, Glasgow; and as the voyages will be of considerable duration, large refrigerated chambers have been provided for food storage. All the woodwork in the crew's accommodation, and also in the fish holds and storage spaces, has been treated with Celcure wood preservative.

* * *

INCREASED LIFT OF NEW FLOATING DOCK

Omission of Tank Tops

By omitting the tank top from the side walls of a new floating dock, it has been possible to save a considerable quantity of material and simultaneously increase its lifting capacity. A system of electrodes have been installed to ensure that the water in the tanks will not rise above a certain level by closing the inlet valves automatically when this level has been reached. The new dock, which has a lifting capacity of 28,000 tons and is able to accept vessels of up to 45,000 tons deadweight, has been built for the owners, Götaverken, A/B., Gothenburg, Sweden, by Jos. Boel and Sons, S.A., Tamise, Belgium.

The dock has been built with ten pontoons and two continuous side walls. The side walls have two decks, one for two 12-ton cranes, the other for manoeuvring labour, materials, etc. Accommodation for the crew of 14 has been built into one of the side walls. Principal dimensions are as follow: length overall, 713 ft. 10 in.; breadth, 132 ft. 9 in.; inside breadth at entrance, 100 ft. 0 in.; height of walls above pontoon deck, 39 ft. 4 in. Work on the dock will be completed by the owners, who will then possess three floating docks with lifting capacities of 28,000 tons, 18,000 tons and 8,000 tons respectively.

MODERN DISCHARGE LAMPS

HAND SKILL AND MECHANISATION COMBINED IN PRODUCTION

There are two main groups of discharge lamps for domestic and industrial lighting: those which use mercury vapour as the medium and those which use sodium vapour. Both are made at the Melton-road, Leicester, works of the British Thomson-Houston Company, Limited. During a recent visit we were able to see the methods used in production. As over 500 types are made at these works, only typical examples will be given.

TUBULAR FLUORESCENT LAMPS

The manufacture of discharge lamps does not lend itself to mechanised production throughout, although many of the separate stages do. The most mechanised production is probably that of the tubular fluorescent discharge lamp which uses mercury vapour under low pressure. Basically, this lamp consists of a glass tube coated internally with fluorescent powder and having at each end a stem carrying a cathode and two anodes. It is shown diagrammatically in Fig. 1. The tube, which is 5 ft. long in the 80-watt size, is filled with argon and contains a small globule of mercury which vaporises when the discharge takes place. The ultra-violet light from this vapour causes the fluorescent coating to emit visible light colour which depends on the coating phosphor used. In production, the stem is automatically made by spinning a flare on a length of glass tubing and inserting, in turn, a length of small-bore tubing for exhausting the lamp and the composite leads for the anode and cathode assembly. The completed stem then passes to another machine in which the leads are bent to shape, the cathode – a coiled-coil wire – is clamped in place and then coated with an emissive material. As the assembly leaves the machine the anode plates are spot welded in place by hand.

The tubes for the body of the lamp are cut to length, washed and dried. They are then stood upright in rubber cups while a suspension of the fluorescent phosphor in nitro-cellulose is forced up them by air pressure, allowed to subside slowly, and the coating dried with warm air. The dried tubes are laid on a roller conveyor which passes them mechanically across a source of radiant heat where the last of the solvent is driven off and the nitro-cellulose binder burnt away. The ends are then cleaned back for a controlled distance by rotating brushes and the quality of the coating is inspected by transmitted light. After inspection, the stem assemblies are mounted vertically on a rotating carrier and the tubes placed over them. Passing through a succession of burners to give the required warming up, the tubes are fused to the stems. The force of the burning gas causes the glass to flow inwards and ensures a sound seal. The tube is then reversed and the second stem sealed in place.

Transferred to the exhausting machine, the lamp is evacuated and baked to drive off impurities. A measured amount of mercury is added, which vaporises on touching the heated cathode and so drives out the last of any other vapours remaining. Argon is added and the tube is finally sealed. On the next machine the end caps are cemented on and the pads of solder applied which give the connection to the lamp holder. After being aged to ensure stable characteristics, it is tested, inspected and packed. The production rate of these tubes is about 600 per hour.

MERCURY-VAPOUR DISCHARGE LAMPS

The medium-pressure mercury-vapour discharge lamps operate at an internal pressure of about one atmosphere. The lamp consists of an arc tube containing a measured quantity of mercury and argon gas at a low pressure. There is a main electrode at each end of the arc tube and at one end a striking electrode for starting the lamp. The arc tube is mounted in an outer jacket containing nitrogen. The construction is shown in Fig. 2.

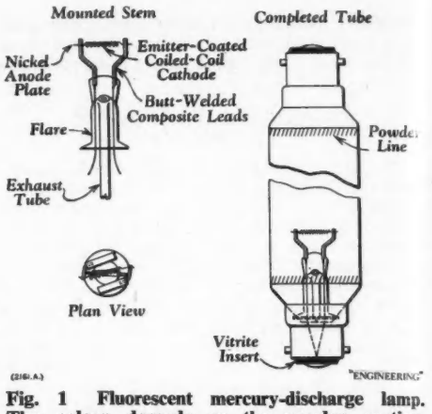


Fig. 1 Fluorescent mercury-discharge lamp. The colour depends on the powder coating.

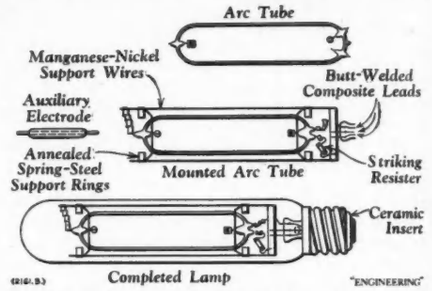


Fig. 2 The mercury-vapour discharge lamp works at approximately atmospheric pressure. It, too, can be coated internally to add red to the light emitted.

When these lamps are connected through a choke to the supply main, the voltage gradient in the small gap between the auxiliary and cap end electrode is sufficient to ionise the argon gas filling of the arc tube and start a glow discharge, the current value of which is limited by a resistor. The initial ionisation reduces the main electrode arcing potential below that of the supply main and an arc commences. Sufficient electron emission to maintain the arc discharge is provided by an emissive pellet within the cathode which is heated to the required temperature by ion bombardment from the arc. The full luminous output is not obtained from the lamp until the arc tube heats up sufficiently to vaporise the mercury and build up the required vapour pressure.

Cathode coils are made by winding tungsten wire on a mandrel in two helix sizes. A small pellet of electron emitter material consisting of thorium oxide, barium, and calcium is inserted into the inner helix which is inserted sideways into the outer helix. This cathode assembly is then welded to the two arms of a welded molybdenum "T" piece which has previously been sleeved with glass. The "striking," or auxiliary electrode is made by glass-sheathing the middle of a short length of plain molybdenum wire. A special glass is used the coefficient of expansion of which is similar to that of molybdenum.

SKILL IN GLASS WORKING

The next process in manufacture is to seal these electrode assemblies into the arc tube bulb. This bulb is received from the Glass Works at Chesterfield shaped similarly to a test tube but with a constriction or neck a little below the mouth. It is made of special heat-resisting

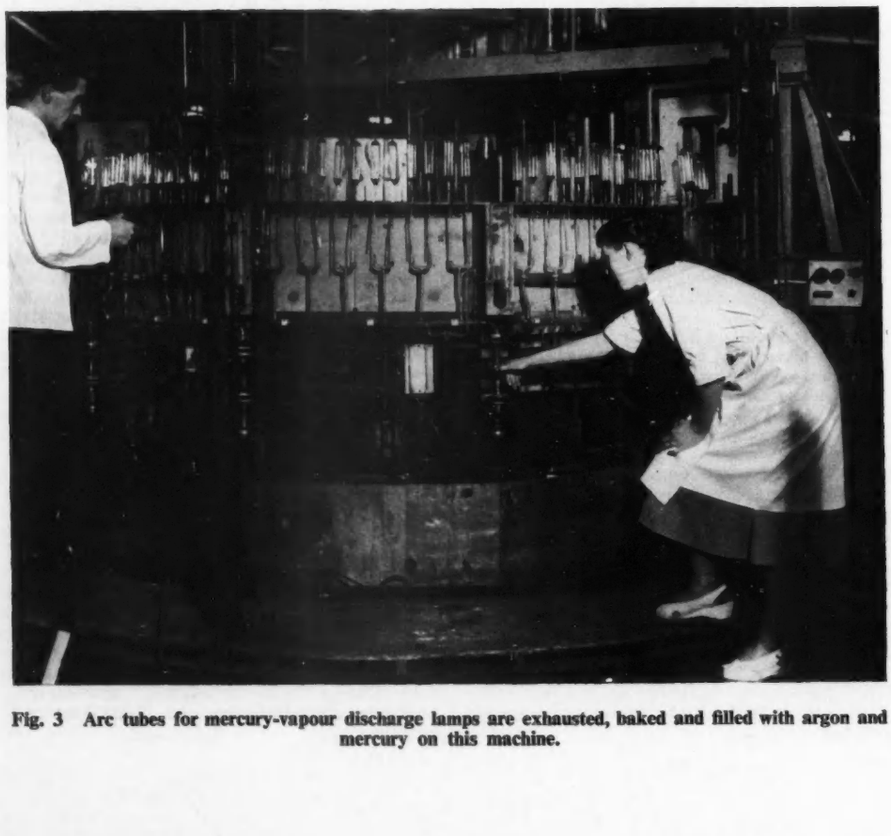


Fig. 3 Arc tubes for mercury-vapour discharge lamps are exhausted, baked and filled with argon and mercury on this machine.

glass and the electrodes are sealed in by highly-skilled glass workers.

The method used is to puncture the dome of the bulb and seal into it a cathode and a striking electrode. An exhaust tube is sealed on between the two. The open end of the bulb is formed into a dome and the second cathode sealed into position. After inspection the arc tube is pre-exhausted, filled with nitrogen and annealed.

EXHAUSTING AND FILLING

A fabricated glass tube assembly is sealed to the exhaust tube and a side arm of the assembly dosed with a measure of mercury. The purity of the mercury is strictly controlled and exactly the right amount must be introduced into the arc tube to obtain maximum light output and life in each voltage range. Immediately before exhausting the arc tube, its ends are painted with liquid platinised paint. This is done to reduce heat radiation from the bulb surface behind the electrodes, thereby improving the rate of vaporisation of mercury in the finished lamp. The arc tubes are sealed to the glass exhaust system on a rotating exhausting, baking and arcing equipment where they are processed and finally filled with spectroscopically pure argon gas and sealed off. By inverting the complete arc tube and glass tubing assembly, the mercury is transferred to the arc tube. It is then sealed off and detached from the tubing assembly. The equipment is shown in Fig. 3. Motion is from left to right and the part illustrated is where the tubes are being attached to the pipework for evacuation by the diffusion pumps which are at the bottom. At the right, the tubes are entering the oven, where the last impurities are driven off and the paint reduced to platinum. The tops of the argon bottles can be seen above the bottom shroud.

The completed arc tube is now mounted between annealed spring-steel discs connected by manganese-nickel wires and mounted upon a glass stem. This assembly will locate the arc tube in the glass outer envelope of the lamp. A titanium-oxide striking resistor and nickel tape connectors are added and the assembly is sealed into the outer envelope at the stem flare rim in a similar way to that used with an ordinary tungsten-filament lamp. It is now only necessary to exhaust the outer envelope and fill it with a controlled low pressure of nitrogen to ensure an inert atmosphere and provide the arc tube with adequate thermal insulation. A cap is fitted and the finished lamp is operated at its full rating for an ageing period to ensure stability in service. After standing overnight the electrical characteristics and quality are tested and the lamps packed.

A higher-rated lamp is made on the same production lines as the one just described, but differs in that it contains a small quantity of metallic cadmium. It is enclosed in a bulb which has the inner surface coated with a phosphor so that some red is added and the colour rendering improved.

HIGH-PRESSURE LAMPS

A high-pressure mercury-vapour discharge lamp works on the same principle as the medium pressure lamp, but owing to the high operating temperatures and pressure of approximately eight atmospheres, it is necessary to construct the arc tube of quartz. Because of the very low expansion coefficient of quartz, it is not possible to use a metal lead wire having "matching" characteristics (alloys of suitably low coefficient of expansion have too low a melting temperature to withstand quartz fusion). Lead-wire assemblies incorporating a length of very thin, feather-edged, molybdenum or molybdenum-tungsten foil, are used. The contour and dimensions

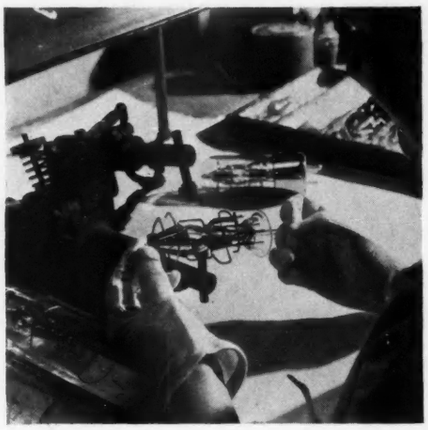


Fig. 4 The spring-steel supporting frame of the compact-source mercury-vapour lamp is spot welded in position.

chosen for such foils provide a permanent vacuum-tight seal with the fused quartz.

The seals are made by inserting the composite metal leads, with quartz spacing strips, into quartz tubes and processing the tubes on a specially-designed machine. Seal making takes only 30 seconds, during which time temperatures in excess of 2,000 deg. C. are attained. The seals are withdrawn from the machine and the electrodes welded into position ready to be sealed into transparent quartz arc tubes. The seal and transparent body are held together in strict relation while the skirt of the body is melted on to the cathode end of the seal. During this operation temperatures in excess of 2,000 deg. C. are again reached and an inert gas is passed over the electrodes to protect them from chemical action.

When both electrode assemblies have been sealed into the body, the unwanted pieces of tube are cut away. The tube exhausting, sealing-in and finishing processes are very similar to those used in the manufacture of the medium-pressure lamps. A true white light can be obtained by a coating giving almost perfect colour rendering.

HIGH-INTENSITY LAMP

The Compact-Source lamp is a high-pressure mercury-vapour lamp used in optical instruments, projection microscopes and for other purposes. A 250-watt size is made and it is available in three versions for special purposes.

The lamp consists of a quartz bulb containing two tungsten electrodes set about 3 mm. apart, between which an arc burns steadily with a brightness in the region of 20,000 candles per square centimetre. This lamp, one of which is shown in course of construction in Fig. 4, is completely hand-fabricated by very highly-skilled craftsmen.

SODIUM-DISCHARGE LAMPS

A sodium lamp consists basically of a U-shaped arc tube in a detachable heat-retaining vacuum flask. The tube is made U-shaped in order to give a long discharge path while keeping the lamp compact. The arc tube contains a quantity of sodium metal and a mixture of neon and argon gas and has an electrode at each end. The discharge is first carried in the neon "starting" gas giving a red light but as the sodium metal heats and vaporises it takes over the discharge. The assembly is shown in Fig. 5.

Cathodes are formed from thoriated tungsten wire coil-coiled on a mandrel. Hydrogen-fired "Fernico" alloy lead wires (iron, nickel and cobalt) are then welded to the cathode legs. "Fernico" alloy is virtually impervious to sodium corrosion and together with the special hard glass sleeves which match the lead wires in coefficient of expansion, provides perfect gas-tight seals. When these seals have been made the cathode is cleaned in hydrogen, dipped in emissive coating solution (barium and strontium carbonates) and then hydrogen-fired again.

TWO-PLY GLASS

A glass tube of two-ply construction, the inner being sodium-resistant, is bent to a U-shape and trimmed to length by machine. A hole is made in the apex and a length of glass tube is then sealed for use ultimately in exhausting the lamp. The assembly is washed before pinch-sealing the cathode assemblies into the ends of the arc tube. The bend in the arc tube and the pinch seals are treated by carefully controlled annealing techniques to ensure freedom from lamp failures due to stresses in the glass at these points. The next operations are carried out on an exhaust machine.

The sodium for the lamps is supplied in a long glass tube and, before exhausting the arc tube, a length is cut off and inserted in the tubulation. The lamp is then sealed to the exhaust system. During the long exhaust process the lamps are arced several times to ensure that every trace of impurity is driven off and pumped away. The sodium metal is then melted by means of high-frequency heating coils causing it to run down into the arc tube. Only pure sodium which has

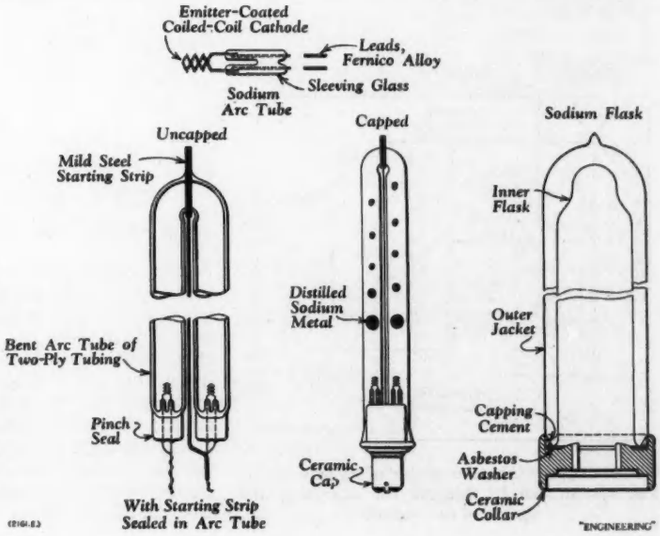


Fig. 5 Stages in the manufacture of a sodium-discharge lamp. The sodium has to be spread along the tube as the vapour tends to hang close to the blob of metal.

been double-distilled is used. The lamp is then filled with a spectroscopically-pure mixture of neon and argon gas and sealed off.

The sodium metal is evenly distributed along the tube by arcing the tube to melt the sodium and then shaking it by hand. Starter strips are fixed in position and the tubes are capped. The lamp is then aged in a vacuum flask and tested. These lamps are contained in a double-walled evacuated flask to keep the temperature high enough to vaporise the sodium.

* * *

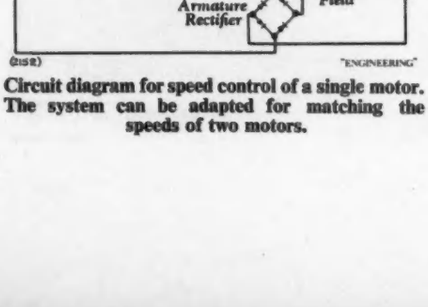
CONTROLLING MOTOR SPEED

Infinitely Variable Adjustment for Single or Multiple Systems

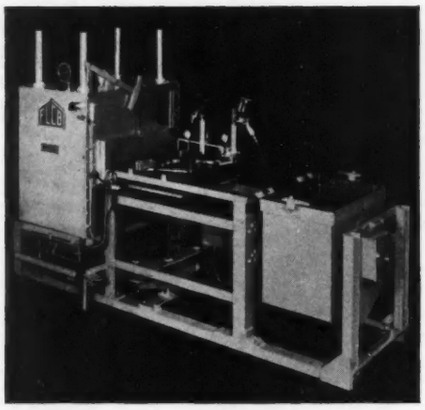
A system of automatic variable-speed control for direct-current electric motors has been developed by M.T.E. Control Gear, Limited, Leigh-on-Sea, Essex, which is entirely self-contained and has no valves or tuned circuits. The basis is the principle of the saturable reactor. A schematic circuit is shown in the illustration below. The circuit as shown is for controlling the speed of a motor by hand adjustment; it can be modified so as to adjust the speed of a secondary motor according to the loading on a primary one.

The mode of operation can be seen by reference to the diagram. Adjustment of the control resistance tapping determines the voltage drop across the main winding of the transductor and this in turn controls the voltage applied to the motor armature. The relay protects the ballast resistance when large and sudden changes in speed are required. When the system is used to control a subsidiary motor, a current transformer is connected in the supply leads of the main motor, the output being rectified separately and fed to the central coil of the transductor. An adjustable resistance would be included so that the speeds could be matched initially. Increase of the load on the main motor would cause the subsidiary to alter speed to relieve the cause.

The equipment is robust and can be handled by inexperienced personnel or used under arduous conditions. Models at present available cover the range from $\frac{1}{4}$ to 3 h.p. Above $\frac{3}{4}$ h.p. it is probably more economical to use a three-phase supply with the transformer connected across the outer phases.



Circuit diagram for speed control of a single motor. The system can be adapted for matching the speeds of two motors.



The Shelmolda Duplus can give an output of between 50 and 60 moulds per hour by accommodating two pattern plates in the one oven. It is semi-automatic and is operated by one man.

IMPROVED SHELL MOULDING

Single-Oven Semi-Automatic Machine

A modified version of the Shelmolda moulding machine (which was described in ENGINEERING, vol. 177, page 27, 1954) has been produced by Fairbairn Lawson Combe Barbour Limited, Leeds. The new model, known as the Duplus, is shown in the picture above. It is said to combine the productive capacity of the two-oven machine with the compactness of a single oven. The proved capacity is stated to be between 50 and 60 moulds per hour, the machine being operated by one man only. The floor space needed is 8 ft. 6 in. by 3 ft. 3 in.

There is a single gas oven, thermostatically controlled, and fitted with a mechanism which enables it to deal with two pattern plates at once and present ready to hand the shell which has just been cured. This mechanism is operated pneumatically. A second automatic mechanism, push-button operated, reverses the dump-box and after a pre-determined time rights it again. These mechanisms remove most of the physical labour from the operator. Investing time can be adjusted and so can the oven temperature; with care the process can be made practically continuous, one mould being cured by the time the second is ready to go into the oven. As in the two-oven machine, pattern plates up to 24 in. by 16 in. are used, giving an effective area of 23 in. by 15 in. Maximum pattern depth is 4 in. and the ejector lift is $1\frac{3}{4}$ in. The dump bin will hold 2 cwt.

* * *

2,500-LB. CAPACITY BULK LOADER WITH FRONT-WHEEL DRIVE

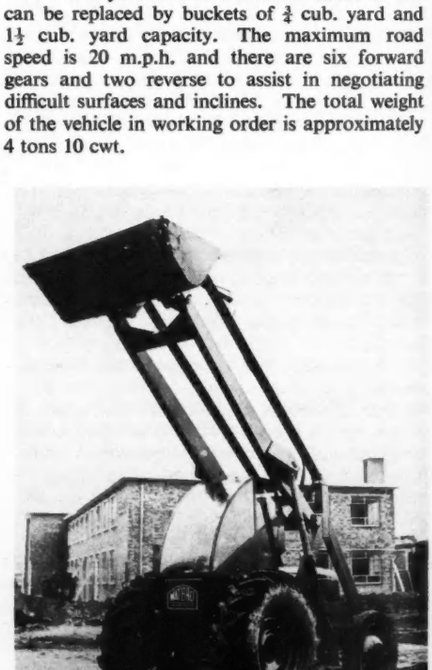
A bulk loader, which the makers state is the first of its kind in this country to use a front-wheel drive, has been introduced by Mathew Brothers, Sandy-lane North, Wallington, Surrey. It is known as the Matbro Super Loadstar and has a capacity of 2,500 lb. The bucket lifting arms have been arranged to give a compensating action; this ensures that the bucket remains at a constant angle relative to the ground throughout the full lift. The compensating action was demonstrated to us, during a recent visit when we were able to inspect the loader, by filling the bucket with water while it was near the ground and raising it without the loss of any of the liquid. Each arm is in the form of a parallelogram linkage, as will be apparent from the illustration below.

The lifting arms are raised and lowered by the action of two hydraulic cylinders, one each side. Tilting of the bucket is also hydraulically controlled by two small cylinders mounted at the ends of the lifting arms. The advantage of the front-wheel drive lies in the fact that the large driving wheels are able to keep a firm grip while cutting overburden or loading, due to the load being taken directly by these wheels. During the demonstration the vehicle was successfully driven along a river bed with the bucket lowered to give the maximum opposition to the drive so that it ploughed up the bed as it went along.

The power unit can be either a Diesel or petrol Fordson Major 40-h.p. engine. The controls are all grouped conveniently inside the cab, which is placed forward of the engine. The transparent hood, which can be seen in the illustration, encloses the driver and gives good all-round visibility. Manœuvrability is assisted by the front-wheel drive. The normal turning radius obtained through the steering action of the new wheels is 162 in. and when the steering brakes on the front wheels are used this can be reduced to 116 in. In operation these brakes can be used to slew the nose of the machine into the desired position.

The lift height under the tipped bucket is 120 in. and to clear a hopper, 150 in. The maximum out-reach from the front of the driving wheel, with the bucket tipped, is 48 in. and with the bucket level 72 in. Eight seconds are required to lift the bucket to its full height and the tilting action takes two seconds. The overall length with the bucket down is 189 in., height 101 in. and width 77 in. The ground clearance beneath the vehicle is 16 in.

A 1 cub. yard bucket is fitted as standard but can be replaced by buckets of $\frac{3}{4}$ cub. yard and $1\frac{1}{2}$ cub. yard capacity. The maximum road speed is 20 m.p.h. and there are six forward gears and two reverse to assist in negotiating difficult surfaces and inclines. The total weight of the vehicle in working order is approximately 4 tons 10 cwt.



The linkage of the lifting arms on this bulk loader maintains the bucket level at all heights of working. Front-wheel drive improves the performance on rough ground.

The new heavy express passenger locomotive for British Railways has three cylinders and poppet valves operated by cams.

EXPRESS PASSENGER LOCOMOTIVE FOR BRITISH RAILWAYS

The latest design of locomotive for British Railways is a three-cylinder 4-6-2 machine with British-Caprotti poppet valve gear. Only one engine has been built, No. 71000, and it has been named after H.R.H. The Duke of Gloucester who was honorary president of the International Railway Congress Association during its recent meeting in London.

The engine has been built at Crewe but was designed at Derby under the direction of Mr. R. A. Riddles, C.B.E., then the member for mechanical and electrical engineering of the former Railway Executive. The British Transport Commission have not described it specifically as one of the series of standard designs, but if it is so regarded it is the last of the 12 designs originally envisaged.

The engine is intended for working heavy express passenger trains and is therefore rated in power class 8. The boiler works at a pressure of 250 lb. per square inch; the three cylinders are 18 in. by 28 in.; the six coupled wheels are 6 ft. 2 in. in diameter; and the tractive effort is 39,080 lb. The principal dimensions and weights are shown in the drawings and in the list below.

Heating surfaces:	
Tubes	2,264 sq. ft.
Firebox	226 sq. ft.
Total evaporative	2,490 sq. ft.
Superheater	691 sq. ft.
Grate area	48·6 sq. ft.
Free flue area	6·8 sq. ft.
Adhesive factor	3·78
Brake per cent., engine and tender	51·17
Minimum radius curve (with specified gauge widening) ..	4½ chains

The boiler is of normal design with riveted joints throughout, and is the same as that fitted to the British Railways class 7 engines except that the firebox is one foot longer. The shell, excluding the front tubeplate, is of 34/38-ton carbon manganese steel, the barrel consisting of two rings, the second ring being tapered and forming a true cone. The two rings are rolled from $\frac{18}{32}$-in. and $\frac{21}{32}$-in. plate, respectively, the outside diameters being 5 ft. 9 in. at the front and 6 ft. 5⅛ in. at the firebox end. The smokebox tubeplate is of the drumhead type, ⅞ in. thick, and there are 40 large flue tubes 5½ in. diameter outside, 7 s.w.g. thick, and 136 small tubes 2⅛ in. diameter outside and 11 s.w.g. thick. The length between tubeplates is 17 ft. 0 in.

The regulator is of the Superheater Company's multi-valve type and is incorporated in the superheater header in the smokebox. It has a connection, controlled by the pilot valve, for supplying steam to return the Caprotti valves to their seats. Access to the regulator valves is by a detachable cover in the top of the smokebox.

A Belpaire firebox with a wide grate is fitted. The steel wrapper plate is ½ in. thick and the inner firebox is of copper with a ⅜-in. wrapper plate. The front of the firebox is extended into the boiler barrel to form a combustion chamber having a 1-in. thick tubeplate. Firebox waterspace stays are of Monel metal, fitted with steel nuts inside the firebox, except alongside the lap joints of the copper door and throat plates, where riveted copper stays are used. The roof and transverse stays are of 25/30-ton steel, the former being riveted on the outside and fitted with nuts on the inside. The longitudinal stays are of 37/43-ton steel. The firebox is 8 ft. 0⅛ in. long outside, the width tapering from 7 ft. 9 in. at the front to 7 ft. 4 in. at the back.

A rocking grate is provided, consisting of 14 rocking sections, seven each side of the centreline. Each rocking section carries 14 renewable finger-type firebar units, making a total of 196 units for the whole grate, and giving a 43 per cent. air space. The two sides of the grate can be rocked separately from the footplate. The ashpan has three hoppers, one between and one outside each of the frames, and is of the self-emptying type, having bottom flap doors on the hoppers, connected by a shaft with universal joints and operated by levers from ground level. Front damper doors on each hopper and the back damper door of the centre hopper are opened and closed by screw gear worked from a handwheel on the fireman's side of the cab. This allows a fine adjustment of the air opening to be obtained.

The smokebox is of the cylindrical type, resting on a saddle which is cast integral with the inside cylinder and the inside slidebar carriers. The twin blast-pipe has plain circular caps each of 4 in. nozzle diameter, and each incorporates a blower ring.

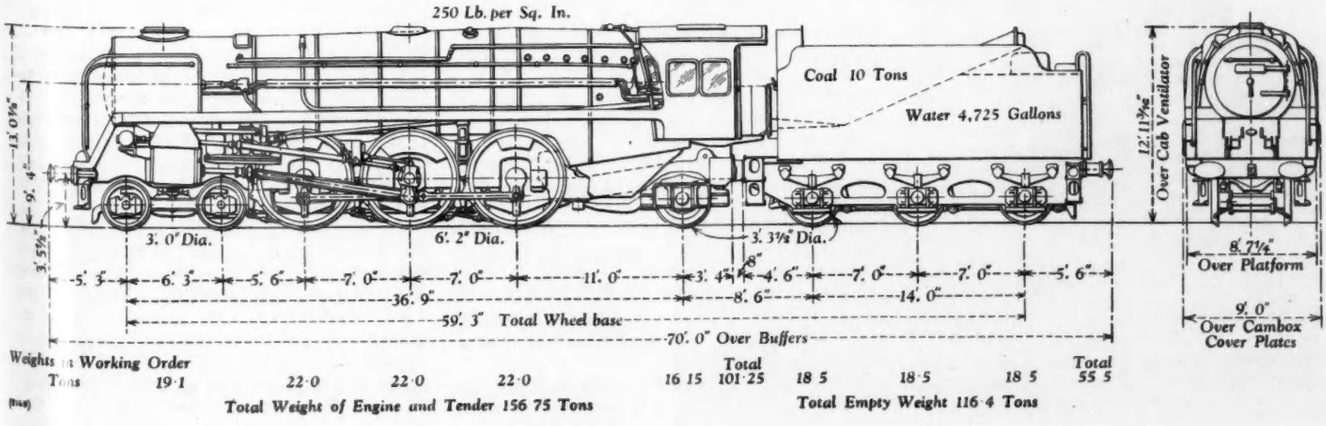
The main frames are 1¼-in. plates spaced 3 ft. 2½ in. apart, the centre-lines coinciding with the centre of the axlebox guide faces. The axlebox guides are welded integrally with the frame plates and fitted with manganese-steel liners. Two of the vertical frame stretchers support the front of the boiler barrel and the firebox throatplate on brass wearing liners, while the back of the firebox is carried on brackets on the rear extension frames. The rear-end frame extension consists of two 2-in. thick slabs riveted to the main plates behind the trailing coupled wheels and carrying a cast-steel dragbox at the hind end.

The engine and tender are carried on Timken roller-bearing axleboxes throughout, those for the bogie and intermediate and trailing coupled axles being of the non-split cannon type. The faces of the axleboxes in contact with the horn guides are provided with manganese-steel liners welded to the body of the axlebox. Springs for the engine and tender, excluding the pony truck, are of the laminated type.

CYLINDERS

The three cylinders are steel castings with cast-iron liners for the cylinder barrels. The inside cylinder, which drives on the leading coupled axle, is located forward of the two outside cylinders which drive on the intermediate coupled axle. The piston heads are steel forgings and are flash butt-welded to the piston rods.

Steam distribution is by means of British-Caprotti valve gear, in which separate inlet and exhaust poppet valves at each end of the cylinder are actuated by rotary cams. The drive for the camboxes on the outside cylinders is taken from the intermediate coupled wheels by means of worm-gear boxes mounted on " return cranks." Tubular shafts transmit the drive from the gearboxes to the camboxes. The drive for the inside cambox is taken from an extension on the wormshaft on the left-hand cambox through a right-angle bevel gearbox. The inside cambox is accessibly placed in front of the smokebox saddle.


250 Lb. per Sq. In.
Coal 10 Tons
Water 4,725 Gallons
13' 0⅛"
9' 4"
3' 5⅞"
3' 0" Dia.
6' 2" Dia.
3' 3½" Dia.
12' 11⅜"
Over Cab Ventilator
8' 7¼"
Over Platform
9' 0"
Over Cambox Cover Plates
-5' 3"- -6' 3"- -5' 6"- -7' 0"- -7' 0"- -11' 0"- -3' 4½"- -4' 6"- -7' 0"- -7' 0"- -5' 6"-
-36' 9"- -8' 6"- -14' 0"-
-59' 3" Total Wheel base-
-70' 0" Over Buffers-
Weights in Working Order
Tons 19·1 22·0 22·0 22·0 16 15 Total 101·25 18 5 18·5 18 5 Total 55 5
Total Weight of Engine and Tender 156 75 Tons
Total Empty Weight 116·4 Tons

From each of the three reversing gearboxes a transmission tube with flange coupling at the rear and spline coupling at the front connects to each respective cambox. Reversing the engine is done by advancing or retarding the angular position of the cams relative to the camshafts, and any cut-off desired is obtained by the angular adjustment of the inlet cams in relation to each other.

Cylinder lubricaton is by means of a mechanical lubricator through atomisers which mix saturated steam with the oil prior to entering the cylinders. The atomisers are controlled by steam taken from the cylinder-cock actuating valve. When the cylinder cocks are closed the actuating valve is open and supplies steam to the atomisers. Conversely, when the cylinder cocks are open the actuating valve is closed and no steam is supplied to the atomisers.

Grease lubrication is provided for the axlebox guides, brake-shaft bearings, firebox supports, bogie bolsters, pony-truck pivot pin and pivot face. The grease nipples are all placed in accessible positions outside the frames.

INSIDE CONNECTING ROD

A feature new to British Railways has been introduced in the method of locking the big-end cotter on the inside connecting rod. It is shown in the illustration below and takes the form of a serrated locking plate, the serrations being phased on both sides of the plate in such a manner that four different positions of the serrations relative to the serrations on the back edge of the big-end cotter can be obtained. This allows an adjustment of $\frac{1}{32}$ in. in the cotter position, and as the taper on the cotter is 1 in 16 a final adjustment of approximately 0·002 in. on the big-end bearing is obtained.

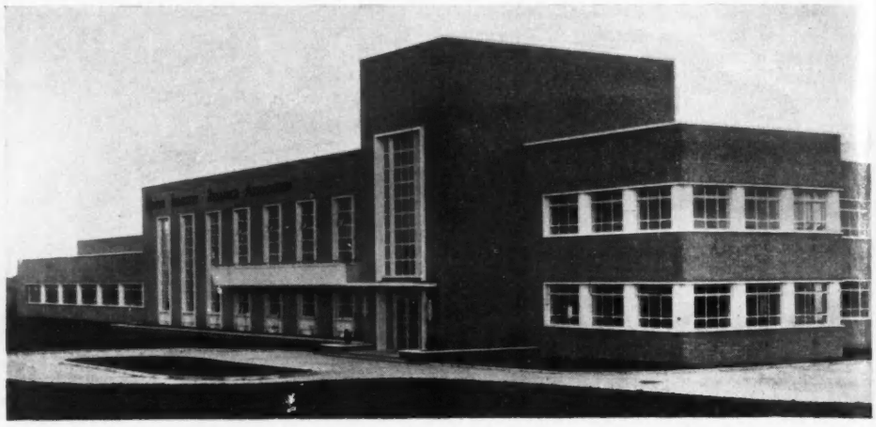
Built-up weights in the coupled wheels balance the revolving parts only.

The engine weight is carried on the bogie by side bolster pads and laminated springs fitted in compensating beams. Side-play control of the bogie is by double helical springs. The engine weight is taken at three points on the pony-truck frame, one being at the pivot centre of the pony truck, and the other two being sliding bolster pads on the truck frame, situated behind the centre-line of the pony-truck axle.

The tender, which has water and coal capacities of 4,725 gallons and 10 tons respectively, has six wheels 3 ft. 3½ in. in diameter, and each axle is fitted with Timken roller-bearing axleboxes. The design of the tank follows generally former L.M.S. practice, except that the side plates have a large radius at the bottom. To provide a coal bunker of increased capacity and of the self-trimming type, it has been necessary to eliminate the rear windows for tender-first working which were a feature of earlier British Railways tenders.

A steam-operated coal pusher is provided and coal sprinkler gear is fitted.

The big-end of the inside connecting rod can be adjusted in steps of 0·002 in. by means of a serrated locking plate.



New research laboratories for the motor industry at Lindley, near Nuneaton.

MOTOR INDUSTRY RESEARCH ASSOCIATION

OFFICIAL OPENING OF PROVING GROUND AND NEW RESEARCH LABORATORIES

Since 1946, when the Motor Industry Research Association was founded to undertake co-operative research for the British motor industry, its value has increased steadily. It began with the laboratories at Brentford previously used by the Institution of Automobile Engineers. In 1949, a disused airfield of some 650 acres at Lindley, near Nuneaton, was acquired, and now built within this area is a vehicle-proving ground which is believed to be the best in Europe, and compares favourably with the proving grounds of large American motor-car manufacturers. More than 100 firms regularly use its testing facilities. Recently the Brentford laboratories were closed and the new buildings, shown above, at the entrance to the proving ground and facing Watling-street, were opened. A plan of the proving ground was given in ENGINEERING, vol. 172, page 12 (1951).

The formal opening of the laboratory and proving ground, by the Rt. Hon. A. T. Lennox-Boyd, M.P., took place on Friday, May 21. Mr. Lennox-Boyd said that one of the difficulties in the export market which the motor industry faced would soon be removed. It would then be possible for vehicles of over 4 tons unladen weight to be made 8 ft. in width. The draft regulations, he hoped, would be issued for consideration before September.

150 M.P.H. ON HIGH-SPEED TRACK

The high-speed track, nearly three miles in length, is triangular in shape with three steeply banked bends. Each bank is 10 ft. 3 in. high and has a slope of 1 in 1½ at the top. It was designed to enable a safe speed of about 100 m.p.h. to be maintained. Already, it has been lapped at a speed of nearly 150 m.p.h. Within the high-speed circuit there is another triangular circuit which began as a half-mile stretch of Belgian *pavé* and was extended to give a 1½-mile circuit. Alongside this is a corrugated track which reproduces the unmetalled " washboard " roads of tropical countries; other test facilities include a shallow water-splash, a dust tunnel, a noise-generating track, a steering pad (a circular concrete bed on which steering tests are made) and a cross-country track.

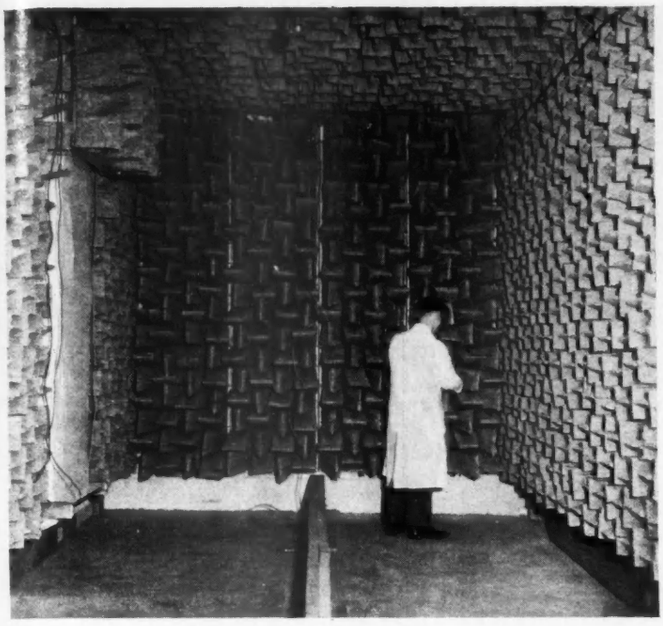
The cross-country track, which is still in the course of construction, is now over three miles long and provides a selection of ruts, gullies, etc., of the kind likely to be found on any unmade roadway. The purpose of the noise-generating track is to provide surfaces which will generate high and low reproducible levels of road-excited body noise in vehicles. The noise is usually recorded on a magnetic-tape recorder so that the result can be taken to the laboratory for analysis. A control tower near the centre of the proving ground is used to regulate traffic. The tower also contains a small meteorological station.

DAILY USE OF PROVING GROUND

An average of 25 vehicles use the proving ground each day; it is open continuously day and night for seven days a week. In 1953, 15,286 vehicle-hours of testing were recorded. Of the 900 member firms 114 regularly use the proving ground, which has in all 12½ miles of tracks and special test roads. The income for maintaining the test facilities is derived from the members, who subscribe two-thirds of its income, either directly or through the Society of Motor Manufacturers and Traders, Limited, and from the Government who make a grant through the Department of Scientific and Industrial Research. The governing body represents all interests in the motor industry, including vehicle operators, the Institution of Mechanical Engineers and the D.S.I.R.

The research laboratories are concerned primarily with fundamental matter, and, in general, do not endeavour to solve the problems of individual companies. The programme of research followed is drawn up by a research committee whose members cover all aspects of vehicle manufacture and operation. The actual work is sub-divided broadly into work on the power unit, on the strength of materials and components, and on the performance of the complete vehicle.

The engine laboratory has eight test bays, each with a concrete bed cushioned on rubber to reduce vibration, and the walls and ceilings are covered with sound-absorbing materials. At present, the use of low-viscosity lubricating oils is being studied in relation to its effect on the mechanical efficiency of Diesel and petrol engines. The object of one of the tests on Diesel lubricating-oils, now in progress, is to determine a test



Problems of noise in vehicles will be studied in this room, which has been designed to reproduce a "free-field." The insulation consists of wedges of Stillite attached by their bases to the walls.

procedure for the assessment of ring-gumming and sticking tendencies of oils in service. The same section is also investigating the loads exerted on a crankshaft while running; this is being done with the aid of wire-resistance strain-gauges.

In another laboratory investigation of the suitability for gears of steels of low alloy content is being carried out. One interesting development suggests that the life of cast crankshafts can be considerably increased. Improvements in bending fatigue-strength of the order of 60 per cent. have been obtained by ball-rolling the crankshaft fillets.

INTERFERENCE WITH DRIVER'S VISION

The amount of interference within the driver's field of vision caused by bodywork is being examined in a novel way. The rig being used is based on methods employed in the United States. It consists of a semi-cylindrical screen placed in front of the car as shown in the illustration below and a flat-back screen behind the car which can be moved about. Two electric lamp bulbs are placed in the positions normally occupied by the driver's eyes. These cast shadows corresponding to the obstruction to the driver's vision produced by the front pillars, steering wheel, etc. The results are plotted on charts and to assist in plotting the screens are marked-off in squares and numbered.

The tests on brake fade are continuing and the problem of brake squeal still remains to be solved. The apparatus installed at Brentford is again being made use of. Tests are being made with the front end of a chassis carrying front wheels, tyres, brakes and suspension. The wheels are turned by motor-driven V-belts, which pass beneath the tyre. Measurements of sound frequency, braking torque, and drum speed are all being made.

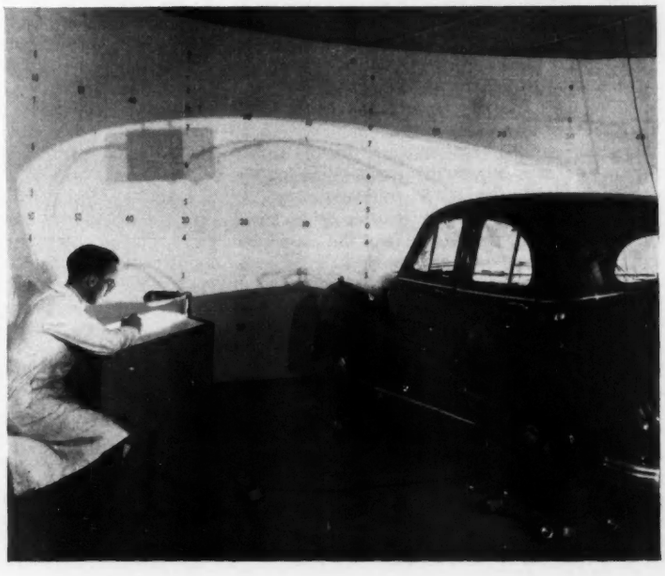
STUDYING NOISE

Noise in vehicles is also being studied in the laboratory. A special room has been built and soundproofed to provide free-field conditions, that is freedom from sound reflections over a wide frequency range. The walls are covered with Stillite, wedge-shaped blocks of this material being fixed by their bases to the walls in the manner shown in the illustration above. The room will be used for the study of complex problems, including the construction of special instruments.

In the chemical laboratory a standard oil-contaminant is being developed. Standard oil contaminants are used in the United States when carrying out tests on engines. The contaminant is added to the lubricating oil used in a test engine to give a condition relating to a known sludge content.

In addition to the laboratories a first-class machine-shop has been provided and a garage has been equipped for the modification and servicing of vehicles using the proving ground. There are also twelve lock-up garages. A canteen caters for the staff, and bedrooms, writing room, and lounge with a television set are available for the staffs of member firms staying overnight.

The technical-information section, which operates with the aid of the library, helps industry by gathering information on automobile engineering published in different parts of the world and issuing it on loan to any members who require information on a particular subject. The collection of information, which has already reached considerable proportions, is growing steadily.



Interference caused by windscreen pillars and other projections in the driver's line of vision are investigated on this rig. Two lights placed in the position of the driver's eyes cast shadows on the semi-cylindrical screen.

PORTABLE HYDRAULIC POWER KIT

For industrial maintenance purposes, Epco Limited, Star Works, Leeds, 7, have introduced a portable hydraulic power kit, known as Flexi-Force.

The Flexi-Force consists of a manually-operated hydraulic pump which forces oil through a high-pressure rubber hose to a hydraulic ram. A range of ram attachments provides for a wide variety of applications, such as pushing gears on to shafts; removing pulleys, gears, and wheels from shafts; pushing ball races into housings; as a hydraulic jack; lifting and lowering machinery and heavy materials; separating press tools and dies; raising an overhead crane off the track; straightening or bending structural sections; and shoring operations. They can also be used in the construction of machines and tools such as straightening presses, aircraft supporting jacks, laboratory presses, strength-testing machines, hydraulic circuit prover, truck tipping gear, hydraulic vices, etc.

The tool is available in two capacities – a 20-ton heavy-duty kit and an 8-ton industrial outfit. They are contained in a metal chest fitted with two lifting handles.

The 20-ton heavy-duty kit includes chains and a chain-plate for pulling; a cylinder-toe for low-level jacking; bases and a pusher head for pressing, pushing, spreading and lifting, and extension tubes and couplings for increasing the span of the main adaptors. The 8-ton outfit consists of a pump, ram and connection. A comprehensive assortment of adaptors suitable for pulling, pushing, lifting, clamping, spreading and bending necessary in all kinds of industrial and maintenance work is included.

The Flexi-Force hydraulic equipment is of pre-fabricated steel construction and there is, it is stated, no danger of hydraulic failure due to casting porosity etc.

* * *

PLASTIC-COVERED STEEL TUBE

A new range of steel tubing known as Burcol, covered with a skin of polyvinyl chloride applied by a special process, has been developed by George Burn Limited, City and Tube Conduit Mills, Smethwick. The polyvinyl chloride coating is resistant to corrosion and has good electrical insulating properties. The tubing is available in off-white, black, red and apple green, in six sizes ranging from $\frac{3}{8}$ in. to $1\frac{1}{4}$ in. outside diameter. Cold-bending of steel tubing coated by the Burcol process can be carried out without difficulty.

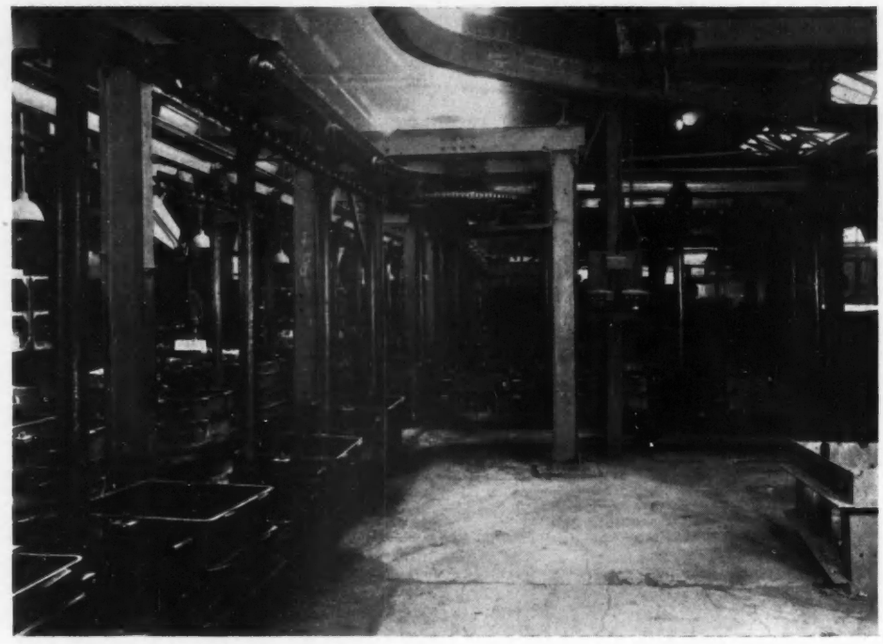


Fig. 1 Overhead pallet conveyor, using two couplings to "share" the driving load and avoid straining the chain. The couplings are also used to give protection in event of a stoppage.

A SIMPLE VARIABLE-SPEED DRIVE

SOME RECENT APPLICATIONS OF A MAGNETIC-SLIP COUPLING

We recently had an opportunity of inspecting some of the latest applications of the Dynamatic coupling made by Heenan and Froude, Limited, Worcester. These couplings were described in ENGINEERING, vol. 169, page 461 (1950), so that only a brief description of their construction will be given here. They consist of inner and outer members linked together magnetically. The strength of the magnetic link, and therefore the relative motion (or "slip") between the members, is controlled by varying the current in the field-coil wound on the inner member. The range of speed of the driven shaft is from 95 per cent. of that of the driving motor, down to almost zero and is continuously variable. Air cooling is used. Speed control is effected either by hand regulation of the rectifier which supplies the coupling with direct current, or by electronic means when automatic control is required.

One of the main advantages of these couplings is that they enable a variable-speed drive to be obtained from a constant-speed motor. This reduces the control gear required when alternating-current motors are being used; the motor can be started under "no-load" conditions and the load gradually applied. Another advantage is that when two drives have to be interlocked, the field coils of the couplings can be connected so that the load is shared equally between them. This is particularly useful for long conveyor belts as it relieves the strain on the belting. Similarly, the speed of a conveyor feed can be automatically controlled to suit the loading on the receiving machine.

FOUNDRY-CONVEYOR DRIVE

An example of "load sharing" was inspected at the West Yorkshire Foundries, Limited, Sayner-lane, Leeds, 10, where an overhead pallet conveyor has been fitted with two drives to relieve the strain. A general view of the conveyor line is shown in Fig. 1. The conveyor, which carries 89 mould boxes along the machine line past the pouring station and during the cooling period, is T-shaped and 356 ft. long. Speed is adjustable up to 20 ft. per minute. The drive is supplied by two 7½-h.p. squirrel-cage motors through V-belts to the couplings and then by worm and spur gears. Control of the conveyor speed enables it to be run at the optimum conditions for pouring – the rate of which depends on the casting being made. Perhaps the main advantage has been the saving in time lost when a jam occurs on the line. Formerly, a shear-pin gave protection, which took time to locate and replace after breakage. Now, an overload on the couplings automatically trips the motor. Travel can be resumed as soon as the trouble is removed. It is claimed by the firm that these two improvements have increased productivity on small castings by 20 per cent.

SPINNING MULE

At Leeds University, experiments have been proceeding with the object of simplifying the spinning mule, the main design of which has hardly changed during 50 years. Instead of the motion being obtained from one central head, separate motors are being used, electrically interlocked. Dynamatic couplings enable the drives to be taken up and slowed down smoothly. They also enable the operation speed to be adjusted to suit the yarn being spun. A full-size machine is being built for trial in a mill.

FELT-HARDENING MACHINE

Fig. 2 shows a Bywaters felt-hardening machine installed at Montague Burton, Limited, Hudson-road Mills, Leeds. The machine is driven by a 15-h.p. motor through the coupling and thence by V-belt to the main shaft. The smaller motor is for raising and lowering the shuffle-plate. Operation of each cycle is fully automatic. The layers of carded material are fed between sheets of canvas beneath the steam-heated plate which clamps down upon them and a "shuffling" action is imparted to it from drives on the vertical pillars. The actual motion is elliptic and the form of the ellipse can be varied. The time during which the material is below the plate, and the speed of the motion, determine the grade of felt produced. The time cycle is controlled from the panel and the Dynamatic coupling provides the means for controlling the motion speed. It has been found that the ability to adjust the variables to the optimum setting, and also the smooth acceleration of the plate has given greater output of a better quality material.

CARPET MANUFACTURE

In the production of needle-loom carpet at Petmar Industries, Limited, Batley, four couplings have been included. Garnet machines weigh out the fibres, card them and then spread the carded layer evenly across the hessian backing which is carried on the main conveyor. It is therefore important that the conveyor speed should be adjustable to match exactly the delivery. The bank of layers then passes beneath the needle-loom, which is driven by another Dynamatic coupling. This enables the frequency of needling to be adjusted to the speed of the belt and to the quality of carpet being made. After needling, the back of the carpet is sprayed with a bonding compound and it passes through drying ovens. A coupling is used to drive the oven conveyors as the speed must conform to that of the production belt. The fourth coupling is used in the drive of the machine for slitting the carpet into strips of the desired width. The production rate of carpet 108 in. wide has been increased

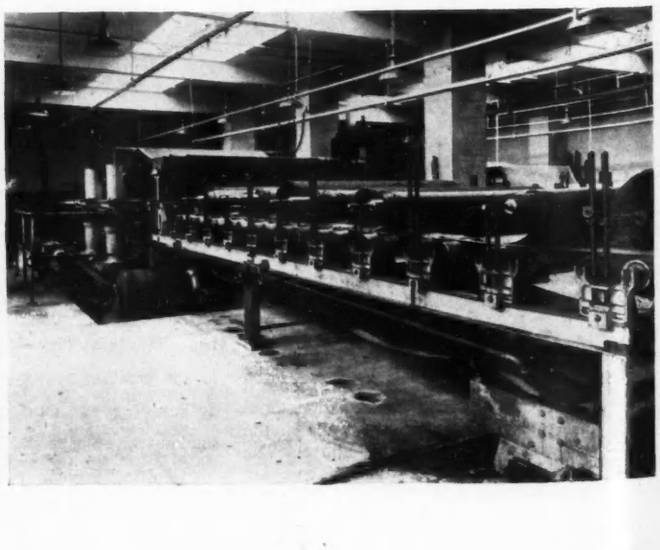


Fig. 2. A Bywaters felt-hardener. The variation of "shuffling" speeds gives control over the quality of the final product.

Fig. 3. Two Dynamatic couplings are used in this slitting machine to control the speed of the coiling drums (which are mounted on square shafts) in order to maintain a constant slitting speed and constant tension in the strip.

steadily up to 7½ ft. per minute by adjustment of the speeds of the various processes to reach the optimum value, while underfelts can be produced at 15 ft. per minute. All the controls are arranged to be operated by one man. A future modification will be the synchronising of the drives by employing one as master and the other three as slaves.

STEEL-SLITTING MACHINES

Samuel Fox and Company, Limited, Stocksbridge, have built two slitting machines incorporating Dynamatic couplings. The machines will slit mild or high-carbon steel strip from 0·006 in. to 0·025 in. thick and up to 8 in. wide. The couplings enable the machines to start smoothly and to accelerate to full speed without any snatch; to maintain a constant strip speed irrespective of the build-up on the receiving drums; to vary the speed up to 500 ft. per minute to suit the strip; and to run either with the cutters driven or as a " pull through " machine. The speed of the strip is pre-set by hand and thereafter all operations are automatic, being electronically controlled. The drive couplings to the coiling drums change in speed as the strip piles up on them so that strip tension is kept constant. Strip speed is maintained by controlling the main coupling from a generator driven by the slitting cutter shaft.

CORRUGATED-BOARD MANUFACTURE

A plant for making corrugated board, incorporating one master and two slave couplings, has recently been installed by the Preston Paper Company, Limited, Walton-le-Dale, Lancashire. Production speed is designed to range from 30 to 300 ft. per minute with a " crawling " speed between 7½ and 10 ft. per minute. The drive to the corrugating machine acts as the master drive for the plant. The second facing is added to the board in the combining machine which, with the drying, cooling, slitting and scoring machines, forms the second section and is driven through a slave coupling. The third section of the plant, also slave driven, is the rotary cutting machine which cuts the board to the required length.

PRECISION POTENTIOMETERS

Different Types Made for Different Laws

Precision potentiometers, incorporating linear or non-linear relationships as required and accurate to one part in 10,000 of a given law, are now being manufactured on a large scale by Salford Electrical Instruments, Limited, Silk-street, Salford, 3, Lancashire. Already used in various types of predictor they are finding many applications in industry, where they are especially applicable to computing devices, automatically-operated servomechanisms and bridge-balancing instruments.

The potentiometers are either card or toroidally wound, both types being accommodated in a standard range of moulded phenolic housings which can be sealed against moisture. The toroidal windings are only made exactly to a linear law, though an approximation to a curve may be obtained. The card windings will fulfil both linear and non-linear laws and can incorporate functions such as sine-cosine relationships, these being obtained by suitably varying the width of the former on which the winding is carried out. Wires down to 0·001 in. in diameter are used for winding and the resolution obtained can be as low as 0·1 deg. depending on the former, wire and wiper diameters. Manufacture is carried out under laboratory conditions in a temperature-controlled air-conditioned shop, special precautions being taken to remove any dust. Part of the shop is shown in Fig. 1. Wiper contacts in these potentiometers are usually made of platinum ruthenium wire and the slip rings are rhodium plated.

Formers for the toroidal type of potentiometer range from 1 in. to 3½ in. in diameter, the normal winding angle being 340 deg. though winding angles up to 360 deg. can be produced. The formers are wound on special machines. A shuttle rotates through the former while it is being rotated slowly in a horizontal plane. The winding machine is fitted with variable-speed devices so that the pitch of the winding can be varied as required. Wires down to 0·0006 in. in diameter can be wound in this way. After winding, the toroids are subjected to a microscopic examination and, when the taps and terminations have been added, are finally tested for linearity and resolution. The tapping points are brazed on by a special process whereby it is possible to pick up a single turn. Taps and termination can be carried out to within 0·5 deg.

Small toroids of this type were first produced for the radio compass in 1947. Since then, however, their application has greatly increased and various types are now available to suit different conditions. Thus the former can be moulded in phenolic or, where maximum accuracy is essential, it can be machined from synthetic-resin bonded paper material. Where the wattage dissipation is high and the temperature is likely to rise above 50 deg. C., a deep-anodised aluminium former is used.

The wire employed is usually enamel-coated, but oxidised coatings are used for the finer wires where the buffing operation for baring the wiping edge of the winding might injure the wire. Toroidal potentiometers of this type have a resistance range from 300 ohms to 500,000 ohms, accurate to within 2·5 per cent. Unlike the card-wound potentiometers, toroidal potentiometers are not wound non-inductively because the relatively larger cross-sectional area makes this inadvisable.

Hard rubber sheet is usually employed for the formers in card-wound potentiometers, though other materials can be used to meet special

Fig. 1 Part of the air-conditioned and dust-free winding shop for the manufacture of precision potentiometers. The final testing equipment is in the foreground.

requirements. The minimum former cross-section dimensions at present are 0·125 in. by 0·015 in. The windings may be linear or non-linear or a combination of both, the width of the former being varied in accordance with whatever law is required. Some are shown in Fig. 2. Accurate former profiles are, therefore, essential factors in the production of this type of potentiometer, and the formers are cut to within 0·001 in. of the calculated shape. A machine has been developed which will cut up to ten formers at once within these limits.

The winding is carried out on an other specially-built machine which will handle wires down to 0·0008 in. in diameter. The wire which is usually employed is Cromaloy V (80/20 nickel chromium), but Constantan or other materials can be used if a different resistivity is required. Particular attention must be given to the enamelling as the thickness of the wire has to be controlled within extremely close limits, since any variation in the pitch of the wire would affect the accuracy of the potentiometer.

Card-wound potentiometers accommodated in standard housings cover a resistance range from 300 ohms to 500,000 ohms, the overall tolerance being ± 1·0 per cent. Resistances outside this range can be catered for, but may need a special housing. Card resistors in the lower resistance ranges may be non-inductively wound, but wires less than 0·002 in. in diameter are not suitable.

After winding, the card potentiometers are subjected to electrical and optical examination. Next the cards are made up into the circular form. First, the necessary short-circuited sections are strapped together by a welding operation. Then taps and terminations are welded on. The card is centred in its circular housing and the wipers are added. Finally the complete unit is calibrated and tested, using a dividing table and a precision ratio test-set.

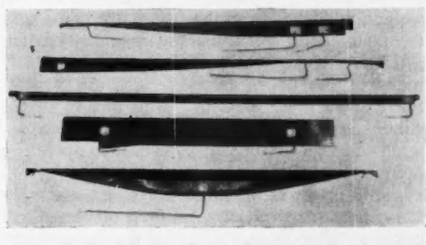
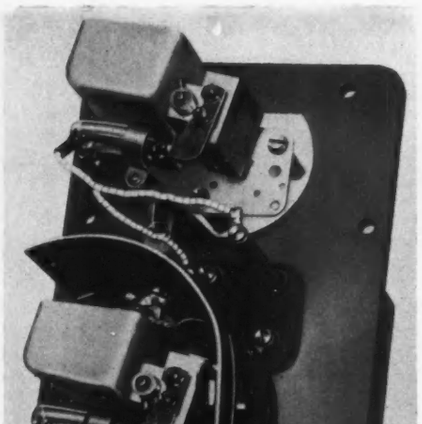


Fig. 2 Examples of card-wound potentiometers (before bending) showing how different laws can be obtained by shaping the formers.



The upper element] of this relay gives warning of a slow fault, and the lower element isolates the transformer if a major fault develops.

GAS-ACTUATED RELAY FOR TRANSFORMER PROTECTION

An improved design of Buchholz-type gas-actuated protective relay, developed by the English Electric Co., Ltd., Stafford, has recently been approved by the British Electricity Authority for use on oil-filled transformers. This type of relay is claimed to be unique in that it detects incipient faults and, by giving an alarm, enables action to be taken before the fault can cause extensive damage to the protected apparatus. It is fitted in the pipe leading to the oil conservator and is available for 1-in., 2-in., or 3-in. pipes.

The relay employs bucket-type operating elements so that the transformer can be vacuum-treated without damaging the relay, and faulty operation caused by punctured floats is avoided. Two operating elements are contained within the casing, as may be seen in the illustration below, the upper element operating an alarm when a certain volume of gas has collected owing to an incipient fault, and the lower element isolating the transformer either on complete loss of oil in the conservator and relay, or when a more serious fault causes an oil surge. The bucket-type elements give positive operation, the values for steady flow and sudden surge being approximately the same. The relay can, therefore, be used on transformers having forced oil cooling. A hand-operated testing device enables the alarm and tripping circuits to be checked rapidly.

Each operating-element assembly consists of an aluminium bucket pivoting on journal-type bearings and counterbalanced by a weight. Both assemblies carry a mercury switch clamped to the weight, and leads from the switch are taken to a terminal block. The curved mercury switch gives positive operation on both the "slow" make of the upper assembly and the "fast" make of the lower element. This type of switch eliminates the oscillatory action usually encountered when the alarm element is near its operating point.

Baffle plates attached to the lower assembly cause it to tilt when struck by an oil surge. A deflector plate is provided on the larger sizes of relay to reduce sensitivity so that a standard lower assembly can be employed on all relays.

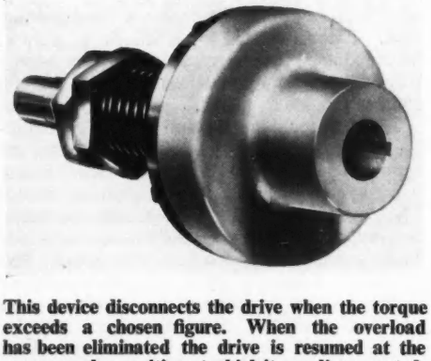
Under normal conditions, the assembly is tilted to the open position. If a slight fault occurs in the transformer, the gas generated will be trapped in the relay housing. As this gas accumulates the oil level will fall leaving the top bucket full of oil. The extra weight due to the contained oil will then overcome the balance weight, and the assembly will tilt, closing the mercury switch and operating an alarm. A cock is provided at the top of the relay for taking samples and releasing gas from the chamber.

With a serious fault the gas generation is rapid, causing the displaced oil to surge through the relay. The flow will impinge on the baffle plate of the bottom element causing it to tilt and close the mercury switch. This will complete the trip circuit and isolate the transformer from the supply. The relay will operate satisfactorily for rising pipe angles between 1 deg. and 9 deg.

* * *

TORQUE OVERLOAD LIMITER

A device for disconnecting the drive should a certain torque be exceeded has been produced by Fords (Finsbury), Limited, Chantry-avenue, Kempston, Bedfordshire. Described as a torque limiter, it is designed to safeguard machines from damage in the event of an overload occurring. A particular feature of advantage in plant where an exact cycle of operations is carried out, as for instance in packaging machinery, is that when the overload is removed the drive will be resumed at the same point of the cycle as that at which it was disconnected.



This device disconnects the drive when the torque exceeds a chosen figure. When the overload has been eliminated the drive is resumed at the same angular position at which it was disconnected.

The principle of operation is that spring-loaded balls rest in holes in the driving plate, lifting clear when the force due to the torque exceeds the force of the spring. The limiter can be inserted in the drive either as a shaft coupling or as part of a chain, belt or gear drive. An electrical cut-out switch can be fitted which will stop the motor when the drive is disengaged. A range of models is made, the one illustrated being adjustable between 100 and 400 lb.-in. and being 10¼ in. long and 4½ in. in diameter.

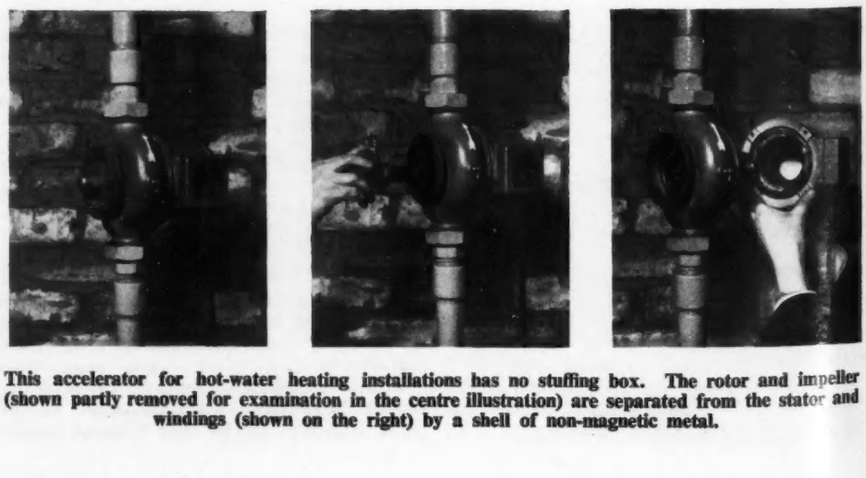
* * *

ACCELERATOR FOR HOT-WATER HEATING INSTALLATIONS

Silent in Action and Requires No Attention

A neat and compact design of accelerator for use in industrial and domestic hot-water central-heating systems is now being made by Sigmund Pumps, Limited, Team Valley, Gateshead, 11. It comprises an electric motor of the squirrel-cage type coupled to the impeller of a centrifugal pump, both motor and pump being combined to form a single self-contained unit, the external appearance of which is shown in the left-hand illustration below. The advantages of forced circulation over thermo-syphon action in a hot-water heating system are well known, but the former has certain drawbacks which the Sigmund Thermopak accelerator, as it is called, has been designed to obviate. It is claimed to be quite silent in action, has no glands, and requires no lubrication or other attention in service.

It should be explained that water has access to the entire rotating element, that is the rotor, shaft and impeller, which are shown removed in the central illustration below, but the rotating parts are separated from the stator and its windings by a shell of non-magnetic metal, part of which is situated in the air-gap between the stator and rotor; the illustration on the right shows the stator removed for examination. The bearings, which are of the sleeve type, are made of stainless steel and bronze and are lubricated by water, no other lubricant being required. The bearings, however, are not located in the main water circuit, water for lubrication being drawn off from the main circuit along the shaft. As no stuffing box is employed, there is no gland leakage, and absolute watertightness is assured. All accelerators are tested under a pressure of 100 lb. per sq. in. They can be operated by single-phase or three-phase current and can be supplied with connections from 1 in. to 4 in. bore, unions being used for the smaller sizes and flanges for the larger sizes. Although examination is rarely necessary, all working parts can easily be inspected or replaced with the aid of a spanner and screwdriver without dismantling any pipe work. We understand that some thousands of these accelerators have been installed in industrial and domestic heating systems in many parts of the world and are giving entirely satisfactory service.



This accelerator for hot-water heating installations has no stuffing box. The rotor and impeller (shown partly removed for examination in the centre illustration) are separated from the stator and windings (shown on the right) by a shell of non-magnetic metal.

LEAD-SULPHIDE CELL FOR INFRA-RED RADIATION

Extreme Sensitivity and Rapid Response to Radiated Heat

A new photo-electric cell with extreme sensitivity in the infra-red has been introduced recently by Mullard, Limited, Century House, Shaftesbury-avenue, London, W.C.2. It is of the photo-conductive lead-sulphide type and in addition to its high sensitivity is characterised by very rapid response, high signal-to-noise ratio, small size and robustness. These features render it of considerable value in numerous industrial applications as well as in various branches of research work. In radiation pyrometry, for instance, very small temperature variations at temperatures as low as 100 deg. C. can be detected, so that the cell can be used for controlling and monitoring in radio-frequency heating without actual contact with the work. With suitable circuit conditions, in fact, the new cell is capable of detecting heat radiations from relatively low-temperature sources at distances of 100 yards or more. It can thus be used for measurements on work moving at high speeds on production lines.

CONSTRUCTION OF THE CELL

The cell comprises two electrodes deposited on a glass disc with a layer of lead sulphide bridging the gap between them. The sensitive element is enclosed in an evacuated glass envelope which, in turn, is enclosed in a metal screening can. The latter is provided with a window through which the radiation passes on to the photo-conductive surface and a two-pin base and holder enable contact to be made with the electrodes. The holder provides for two methods of mounting: the normal method is by means of a flange, but the flange can be easily removed and the cell can then be mounted in a narrow tube. The diameter of the cell is $\frac{3}{4}$ in. and the overall length, including the holder, is $1\frac{3}{4}$ in.

WAVELENGTH RESPONSE AND SENSITIVITY

The operation of the cell depends upon the fact that the resistance of the lead-sulphide layer changes linearly with the amount of infra-red radiation falling on it. A polarising voltage of 150 volts is applied to the electrodes and the change in the resistance of the lead sulphide produces a voltage change across an external resistive load. The voltage changes can, of course, be amplified many times and used to operate meters, alarms, electro-mechanical controls, etc. The resistance of the lead-sulphide layer lies between 2 and 7 megohms, its average value being 4 megohms, and the load resistance generally employed is between 1 and 2 megohms. It is therefore possible to operate the cell using conventional alternating-current amplifier techniques.

The wavelength response of the cell is from about 0·3 micron (= 3,000 Å) in the visible spectrum to about 3·5 microns (= 35,000 Å) in the infra-red, the peak response occurring at 2·5 microns (= 25,000 Å). For comparison purposes it may be noted that the upper limit spectral sensitivity of emission cells of the cæsium/oxidised-silver type ceases at about 1·2 microns (= 12,000 Å).

The cell, it should be mentioned, has an inherently large ambient-temperature coefficient of resistance and to minimise the effect of this it is usual to interpose a " chopper " disc or similar device between the cell and the source of radiation to be detected. The output of the cell is then fed to an alternating-current coupled amplifier the time constants of which are chosen so that only the rapidly changing signals resulting from the " chopping " are passed on to the subsequent amplifier stages. The best results are obtained by using a " chopper " frequency of about 800 cycles per second. The amplifier is of the tuned type with a band width of 50 cycles. With this arrangement it is possible to detect radiation energies as low as 0·003 microwatt, which is equivalent to the radiation from a black body at 200 deg. C. passing through an aperture 3 mm. in diameter and situated at a distance of 20 cm. from the cell. To indicate this degree of sensitivity in more practical terms it may be mentioned that the cell will detect directly, without any optical system, the heat radiation from an ordinary soldering iron (temperature about 350 deg. C.) at a distance of 100 yards. The makers' designation for this particular cell is 61 SV.

* * *

LININGS FOR MOLTEN-METAL LADLES

Longer Life and Less Trouble

A short time ago the Morgan Crucible Company, Limited, Battersea Church-road, London, S.W.11, introduced a plumbago liner for molten-metal ladles in foundries. These liners are, in effect, lipped crucibles shaped so as to fit snugly into the steel shells of the ladles. They give much longer lives than the conventional loam facings and possess other advantages. Among these may be mentioned the " non-wetting " properties of graphite, which ensure a smooth interior surface to which metal and slag do not readily adhere, and also the fact that there are no loose particles to cause non-metallic inclusions in the melts. As the liners are pre-fired they are free from combined moisture and do not cause gas to enter the metal or bring about porosity. Moreover, there is no need to dry-out the linings daily but only to preheat them before receiving the first charge. Once fitted into the ladle they require no patching or maintenance and a longer life is obtained from the outer steel shells of the ladle.

Reports from users which the makers have received bear out the original claims and emphasise the advantage of this method of lining ladles over the existing practice of doing the work at frequent intervals by applying some form of sand or fireclay to the interior of the ladle.

Thus, " lives " of 1,958, 2,124 and 3,250 pourings were obtained from linings of 25-lb. capacity ladles holding molten Meehanite. A life of 1,850 pourings was obtained from a lining of a 195-lb. capacity ladle also containing Meehanite, and 10 such linings averaged 1,500 pours. In a bronze foundry a 245-lb. capacity lining had a life of 1,149 pourings when used for phosphor bronze and of 1,500 pourings when employed in connection with beryllium copper.

A recent development of the liner has been the adoption of a replaceable slag baffle plate which fits vertically into the liner.

* * *

2,000-H.P. DIESEL-ELECTRIC LOCOMOTIVE

Mixed-Traffic Unit for Southern Region

A 2,000-h.p. 1 C_o-C_o 1 Diesel-electric locomotive has recently been completed at the Brighton Works of the Southern Region of British Railways and is to be used for mixed-traffic purposes. It weighs 132·8 tons, of which 109·5 tons are adhesive. The starting tractive effort is 50,000 lb. and the maximum speed 90 m.p.h.

The mechanical construction of this locomotive is generally similar to that of the two earlier 1,750-h.p. locomotives and the air-brake equipment and the two driving cabs are also practically identical with those on the earlier machines. The engine was constructed by the English Electric Company, Limited, Kingsway, London, W.C.2, and is that firm's 16-cylinder V-form four-stroke pressure-charged type. It is provided with four Napier superchargers, while the governor is of the variable-speed hydraulic servo pattern and is driven through bevel gearing from one camshaft. It is arranged for remote operation from the master controller by compressed air and is designed to give full torque control from 450 to 850 r.p.m.

The ten-pole main generator is directly coupled to the engine and at 850 r.p.m. has an output of 1,750 amperes at 965 volts. It is cooled by a fan attached to the engine flywheel and barring ring. The overhung auxiliary generator, which is bolted to the bearing end plates of the main generator, is a shunt-wound machine with an output of 48 kW at 135 volts. From it, current is supplied to all the auxiliaries, except the radiator-fan motor, and to a 236-ampere-hour lead-acid battery.

The six traction motors are of the series-wound force-ventilated type and are permanently connected in three groups of two in series. The control equipment consists of electro-pneumatic and electromagnetic switches and, like the pneumatically-operated engine throttle, is actuated from a main power handle in the cabs. The cabs also contain a master switch with four positions: " off," " forward," " reverse " and " engine only." There are three stages of field-weakening by non-inductive shunt, the minimum field being 25 per cent.

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ANTI-STRIPPING AGENT FOR TAR PRODUCTS

Avoiding Delays in Wet Weather

For tar and bitumen compounds to be successfully placed in wet conditions, it is necessary to use an anti-stripping agent. This is true whether the products are being used for soil stabilisation, as binders for stone in road surfacings, or for protective coatings for pipes or structural steelwork. If such an agent is not used then an early fall of rain is likely to wash the tar off the stone or steel which it is intended to protect. The stability of tar coatings can be increased by the use of suitable anti-stripping agents, one of which is stearine amine.

Stearine amine is an aliphatic amine of high molecular weight which, because of its long straight chain molecule, is able to promote adhesion as a surface-active agent by lowering the surface tension between the binder and the stone and thereby act as an anti-stripping agent. In the form of a solid crystalline product, stearine amine is marketed in the United Kingdom by Ruddock and Meighan, Limited, Burford House, Wealdstone, Middlesex. The solid crystals will melt at about 120 deg. F. and will dissolve in warm tar or bitumen; it is insoluble in water but is soluble in many organic solvents. It is normally sold moulded into easily-breakable cakes, but, as it has an organic basis of primary amines it should be handled with the same strict care as alkalis. The distributors recommend that industrial gloves should be worn when handling the raw material. It is packed and dispatched in bags containing 75 lb., which is sufficient for treating 500 gallons of binder to the normal concentration of 1·5 per cent.

Labour Notes

FOUNDRY EMPLOYEES' CONFERENCE

Suggestions for improving health and safety arrangements in foundries were among the motions on the agenda of the five-day annual delegate meeting of the Amalgamated Union of Foundry Workers, which was held at Southport and ended to-day.

One of the union's districts affirmed that there was grave concern at the absence of a plan for the establishment of an occupational health service and demanded that the Government should immediately institute an inquiry into the problems of occupational disease and injury.

By the terms of the same resolution, the Government was asked to undertake "a comprehensive scientific survey, medical and technical, of diseases generally, accidents, working methods, materials, and environmental conditions." The Government was also asked to increase its grant to the Department of Scientific and Industrial Research, by a substantial amount, in order that existing research in occupational health and safety precautions might be extended over a much wider field. The district suggested that more doctors should be trained in industrial medicine.

SAFETY PRECAUTIONS

There were several motions demanding the issue of protective clothing, including non-inflammable aprons for dressers and a six-monthly issue of boots, free of expense to employees. In view of the complaints that are made from time to time that workpeople often fail to wear their protective clothing, the attention given by the conference to this matter may be interpreted as an indication that the need for making full use of such clothing is being more widely understood.

Another resolution sought to improve the "inadequate" service provided by H.M. factory inspectorate, and suggested that, when inspectors visited factories, they should be accompanied by the shop steward concerned.

One district demanded that all industrial X-ray services should be taken over by the National Health Service, while another area considered that trainees under the Ministry of Labour rehabilitation scheme should be paid at the full trade-union rate applicable to their former occupations, thereby obviating unreasonable sacrifices in the case of sufferers from pneumoconiosis and scheduled diseases.

NATIONALISATION OF ENGINEERING

The conference was asked to express its "profound disappointment and grave concern" at the absence of a plan in the Labour Party's pamphlet *Challenge to Britain* for the nationalisation of the engineering and shipbuilding industries, as suggested by the Confederation of Shipbuilding and Engineering Unions.

With respect to schemes for the public ownership of these industries, it was suggested that the delegates should condemn "the document *Challenge to Britain* as being inconsistent with the unanimously declared policy of the 39 unions comprising the Confederation."

In his report to the conference, Mr. J. Gardner, the union's general secretary, reminded the delegates that the Confederation's "Plan for Engineering," referred to in the above-mentioned resolutions, had been stigmatised from the platform at last year's conference of the Labour Party, by a prominent trade-union leader, as a "mumbo-jumbo of meaningless phrases" and the "greatest abortion ever conceived in the mind of man."

Mr. Gardiner roundly condemned these outspoken criticisms of the Plan and recalled that the Confederation's original memorandum had been modified to meet the objections of this and other critics. He summed up the matter by quoting from a recent resolution of the A.U.F.W., which declared that the most effective basis on which a scheme for engineering could be developed to fit in with an overall economic plan, was to bring all sections of the engineering industry under public control.

RAILWAY DISPUTE ON LODGING TURNS

A stoppage which gave signs of developing into a widespread and bitter dispute came to an end last Saturday, when enginemen on the Western Region of British Railways, who had been on unofficial strike, agreed to resume work as from midnight on that day.

This, accompanied by the decision of footplate crews at the principal depots on the Eastern and North Eastern Regions not to come out on strike, has led to rapid progress being made in the restoration of the railway services during the past few days.

The decision of the Western Region men to return to work was taken at the end of a meeting which had lasted nearly ten hours and was probably largely a result of the new policy of the Associated Society of Locomotive Engineers and Firemen to agitate for the abolition of all lodging turns. It was taken on the understanding that the union would commence negotiations at once with the British Transport Commission.

The men's view that negotiations on the subject could be commenced immediately was, perhaps, unduly sanguine, as the decision of the A.S.L.E.F. to press for the abolition of lodging turns was reached only at the annual delegate conference on May 27 and is completely at variance with the union's previous attitude.

The union's executive council must consider the new policy in detail and consult the National Union of Railwaymen, to which many enginemen belong, before it is in a position to begin negotiations with the British Transport Commission.

UNION'S CHANGE OF POLICY

At some of the depot meetings on the North Eastern Region, decisions not to take strike action are reported to have been carried by only small majorities, and, on both the North Eastern and Eastern Regions, there is much uneasiness regarding the proposed introduction of additional lodging turns in the near future.

Suggestions were made at the meeting of footplate men at Newcastle-upon-Tyne on Sunday that the railway management were due to introduce 58 new lodging turns on the North Eastern Region at an early date. The men carried by a large majority a resolution demanding that the A.S.L.E.F. and the N.U.R. should insist that the British Transport Commission cancel their plans for additional lodging turns, including those arranged to commence on June 14.

The meeting agreed that, if these turns were not abandoned, another mass meeting of enginemen should be called to consider what further action should be taken.

A few days previously, official announcements had been made by the North Eastern and Eastern Regions that, although no new turns would be introduced on the North-Eastern area, for the time being, 49 additional turns would come into force on the Eastern area, commencing on June 14. These would operate at main-line depots between King's Cross and Doncaster.

The locomotive grades committee for the North-East district of the N.U.R. met at Darlington on Sunday and passed a resolution urging all branches of the union to demand that their national executive council should press for the abolition of all lodging turns.

Such a motion, if approved by the union's annual conference in July, would bring the official views of the N.U.R. into line with the new policy of the A.S.L.E.F. Until May 27, when the latter union decided to agitate for the abolition of lodging turns, both unions agreed to small numbers of such duties on the ground that they were necessary for the efficient operation of the railway services.

NEED FOR ACTION TO IMPROVE COAL PRODUCTION

Anxieties regarding the present level of coal production, which has declined to the point where it may not be possible to accumulate sufficient stocks for autumn requirements, were discussed at a meeting between members of the National Coal Board and the national executive committee of the National Union of Mineworkers on May 28.

The view was expressed, in a statement issued after the meeting, that the problem was one which could only be tackled by local action and that special attention should be paid to pits where production was below what might reasonably be expected.

To this end, Divisional Coal Boards and area executive committees of the union were being asked to take joint action wherever possible, and to report within a month what was being done and what remained to be achieved.

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NOTICES OF MEETINGS

Incorporated Plant Engineers

LIVERPOOL
"Economy in Process Steam," by H. E. Lake. Merseyside and North Wales Branch. Radiant House, Bold-street, Liverpool. Mon., June 21, 7.15 p.m.

MANCHESTER
"Peak Loads and Heat Storage," by W. Goldstern. Engineers' Club, Albert-square, Manchester. Tues., June 8, 7.15 p.m.

NEWCASTLE-UPON-TYNE
"Planned Maintenance System," by T. F. Hutchinson. North-East Branch. Roadway House, Oxford-street, Newcastle-upon-Tyne. Thurs., June 10, 7 p.m.

Institute of Metals

LONDON
"The Brittle Fracture of Metals: Some New Developments," by Professor E. Orowan. Wed., June 30, 5 p.m.

Institution of Civil Engineers

LONDON
Annual General Meeting. Tues., June 8, 5.30 p.m.

Royal Meteorological Society

LONDON
"Computation of Tendencies and Vertical Motion with a Two-Parameter Model of the Atmosphere," by F. H. Bushby and M. K. Hinds; "The Computation of Forecast Charts by Application of the Sawyer-Bushby Two-Parameter Model," by F. H. Bushby and M. K. Hinds; and "The Evaluation of Infra-Red Radiative Fluxes Due to Atmospheric Water Vapour," by W. L. Godson, 5.15 p.m. Preceded by a Special General Meeting at 5 p.m. Wed., June 16.

Royal Sanitary Institute

BATH
"Chemical Agents and Poisonous Metals in Foods," by A. Tyler, and other papers. Pump Room, Bath. Fri., June 11, 10.15 a.m.

Women's Engineering Society

LONDON
Annual General Meeting. Wed., June 16, 7 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of Metals, 4 Grosvenor-gardens, London, S.W.1. (SLOane 6233.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Royal Meteorological Society, 49 Cromwell-road, South Kensington, London, S.W.7. (KENsington 0730.)
Royal Sanitary Institute, 90 Buckingham Palace-road, London, S.W.1. (SLOane 5134.)
Women's Engineering Society, 35 Grosvenor-place, London, S.W.1. (SLOane 0401.)